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NORMAL AND PATHOLOGICAL.

CONDUCTED BY

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THE DEVELOPMENT OF THE SUSPENSORY LIGAMENT OF THE FETLOCK IN THE FŒTAL HORSE, OX, ROE-DEER, AND SAMBRE-DEER. By D. J. CUNNINGHAM, M.D., F.R.S.E., *Professor of Anatomy, Royal College of Surgeons in Ireland.* (PLATE I.)

IN a series of investigations into the homologies of the intrinsic pedal muscles of the Mammalia (the results of which are published in the Reports of the Challenger Expedition)¹ I was led to the belief that the suspensory ligament of the fetlock in the foot of the horse, is formed by the fibrous transformation of the short flexor muscle of the middle digit, and further, that the corresponding structure in the ox, sheep, and camel is developed by the coalescence and fibrous metamorphosis of the short flexor muscles of the middle and annular digits.

The muscular origin of this ligament in these animals has long been known—indeed it could hardly be otherwise, seeing that in almost every case it bears its history on its face. Upon both surfaces streaks of striated muscular fibres can, as a rule, be detected, and when thin microscopic transverse sections are made through its substance, the fleshy fibres are observed to penetrate deeply into its midst.

In sections through the suspensory ligament of the adult horse, the fleshy fibres appear in the form of two crescentic outlines placed side by side. These represent tracings of the two heads of the flexor brevis medii, from which the ligament is developed. When examined by the low power of the microscope, it is seen that the muscular tissue is present only in patches, and that the intervals between these are filled up by

¹ "Report on the Marsupialia," part xvii., 1882.

collections of fat cells, with numerous transversely divided nerves and blood-vessels. Further, it may be observed that the fat cells even encroach upon the fleshy patches, and insinuate themselves between the fibres, many of which are in an advanced state of fatty degeneration. Even to the naked eye the crescentic outlines exhibit an alternation of opaque yellowish and light portions, and are very jagged and irregular.

In sections through the suspensory ligament of the adult ox and sheep, four circular outlines, placed side by side and nearer the deep than the superficial surface of the structure, are observed. These represent tracings of the four heads of the two short flexors which amalgamate and transform to constitute the ligament.

In the ox the outlines are slightly convoluted or sinuous, and are very strongly marked; further, they are formed almost uninterruptedly of muscular fibres. Groups of fat cells, it is true, are to be detected here and there with nerves and blood-vessels in their midst, but these never attain such a development as to break up the continuity of the solid fleshy tracings.

The constitution of the four circular outlines in the suspensory ligament of the sheep is very different. They are formed almost entirely of fat cells, with nerves distributed at intervals throughout them. Blood-vessels are also present, but they are exceedingly minute. Hardly a trace of muscular tissue is to be seen, and what is present is in such an advanced state of degeneration that it is scarcely recognisable. Indeed, in many sections it cannot be detected, and in my first investigations I failed to discover it (Challenger Reports, "Marsupialia").

A study of the suspensory ligament of the fetlock, even in adult specimens of these animals, shows therefore with tolerable clearness the steps by which the original muscle or muscles have been transformed into fibrous tissue. It is an instance of a *pathological* change assisting a *morphological* process. The metamorphosis is effected by a fatty degeneration and infiltration of the muscular tissue, with a coincident multiplication of the connective-tissue elements. The nerves are retained throughout the entire change, and remain apparently unaffected. As the muscular fibres become gradually reduced in numbers, the blood-vessels apparently suffer a diminution in calibre.

All this, however, I have already in a great measure described, but I have always felt that the research was incomplete, and the chain of evidence imperfect, so long as the foetal condition of the ligament was unknown. For some time, therefore, I have been on the outlook for foetal specimens of these animals, but it is only very recently that I have been able to obtain them. My friend Mr Geddes, Lecturer on Zoology in the Edinburgh School of Medicine, supplied me with a foetal horse and a foetal roe-deer, whilst Professor Purser of the University of Dublin was so good as to give me the hind and fore-feet of two foetal oxen.

The feet of the foetal horse were placed in a saturated solution of picric acid, whilst those of the other specimens were immersed in the ordinary decalcifying mixture of chromic and nitric acids. When a proper consistence was obtained, a continuous series of transverse sections through the metacarpus and metatarsus of the fore and hind-foot of each animal were made by means of Rutherford's freezing microtome. These were classified according as they were taken from the upper, middle, or lower third of the metacarpus or metatarsus.

HORSE (figs. 1, 2, and 3).

The foetal horse had apparently reached the fourth or fifth month of intra-uterine life. I am unable to give its measurements, as the head had been sent to Professor W. K. Parker before it came into my possession. The antero-posterior diameter of the foot, however, measured half an inch, whilst the transverse diameter measured a quarter of an inch. In the sections through the middle third of the hind foot of this specimen, the structure of the suspensory ligament of the fetlock is well seen (fig. 1, *l*). The two crescentic outlines are very evident, and in relative size and figure are somewhat similar to those observed in the fully developed ligament. One essential difference, however, is that not a trace of fat cells is to be seen, and the outlines are consequently entirely muscular in their constitution. The fleshy fibres are embryonic and indefinite in character, and are closely packed together, so that the tracings are not jagged and irregular as in the adult, but compact, continuous, and solid. Minute blood-vessels and nerves are plentifully scattered throughout this muscular tissue.

It is a difficult matter to compare with accuracy the relative amount of muscular tissue in the suspensory ligament in its foetal and adult conditions. It certainly appears, however, to be slightly in excess in the foetal structure.

In the sections through the upper third of the foot (fig. 2, *k*) the areas of ligamentous tissue enclosed by the muscular outlines are smaller, and the fleshy fibres appear more fully developed and more abundant. In addition to this the tracings have a slightly different figure and relative position. The outline representing the inner head of the flexor brevis medii, has an elongated oval form, and lies behind (*i.e.*, superficial to) the external muscular tracing. The latter retains its crescentic outline. As in the middle third of the foot the outlines are entirely muscular, with not a trace of adipose tissue.

As the ligament is traced down through its middle third to the point where it bifurcates, the fleshy fibres in its substance gradually disappear.

An examination of the suspensory ligament, as seen in the sections through the fore-foot, gives very similar results. Throughout the entire length of the structure the muscular tissue shows not a trace of fatty admixture. The fleshy fibres are more abundant than in the pes, and in certain parts of the ligament are grouped somewhat differently. High up in the upper third they present two very jagged irregular figures (fig. 3, *c*); in the middle third they take the same form as in the pes, but the crescents are somewhat larger; in the lower third the outer portion of each crescent becomes very slender, and the fibres aggregate chiefly in its inner portion, which becomes correspondingly thickened; lastly, immediately above the bifurcation, the outer part of the crescent disappears, and the muscular tissue is present in two masses placed close together in the centre of the ligament. These masses, as seen in transverse section, run in the antero-posterior direction, and are in direct continuity with the thickened inner portions of the crescents higher up the ligament.

Ox (figs. 4, 5, 6, and 7).

The feet of the foetal oxen were taken from two specimens—one a foetus seemingly of about five months, and the other much

earlier, not more perhaps than three months. In the more advanced specimen the antero-posterior diameter of the pes was three-eighths of an inch, and the transverse diameter rather more than a quarter of an inch; in the early foetus the antero-posterior diameter of the pes measured one-eighth of an inch.

In both cases the muscular fibres present in the substance of the suspensory ligament are much more plentiful than in the adult. In the more advanced foetus (fig. 4, *a*) they constitute fully one-third of the entire bulk of the ligament, whilst in the early foetus (fig. 6, *a*) they form very nearly half of its bulk. This muscular tissue is arranged in four masses quite distinct from each other, and represents as in the adult the four bellies of the flexor brevis medii and flexor brevis annularis.

In the ligament of the early foetus, each of these aggregations of fleshy fibres presents in transverse section the form of an arch (fig. 6, *d*) the piers of which reach the deep or metatarsal surface of the structure, whilst the convex or curved part is turned towards its superficial surface, and is separated from it by a thin layer of tendinous tissue.

An examination of the sections taken from the pes of the more advanced foetus exhibits a considerable change in the construction of the ligament. The relative amount of tendinous tissue is distinctly greater and the fleshy masses have assumed a somewhat different shape (fig. 4, *a*). They now appear more in the form of rings with thick and solid fleshy outlines. The arrangement has therefore a closer resemblance to the condition observed in the adult. The change from the arched to the annular form of the muscular masses is brought about by the approximation of the two piers of each arch. In no case, however, do these fuse, and thus the rings are imperfect upon their metatarsal aspect. In addition to this the fleshy outlines, which in the very early foetus are uniform, are now at certain points sinuous and convoluted, as if the increase in the amount of tendinous tissue had affected them in such a manner as to alter their figure.

The muscular fibres composing these arches and rings in the substance of the ligament are embryonic in character. They are closely pressed together, and not a trace of adipose tissue is to be observed associated with them. Several blood-vessels and nerves are present in each fleshy mass.

At the point where the ligament divides, the muscular masses pass one into each of its four primary divisions. This may be observed in figure 5, which represents a section through the lower third of the ligament. In this the two lateral parts of the ligament (*b* and *g*) have separated, whilst the two central portions (*d* and *e*) are in process of separation. Each division carries with it the muscular remains (*c*, *a*, and *f*) of the fleshy belly from which it originates. The muscular tissue, however, is somewhat different in its arrangement at this level.

In the fore-foot of the foetal ox, the muscular tissue in the suspensory ligament is slightly in excess of that in the corresponding structure in the pes. It is also not so uniformly disposed in its midst. It is true that four separate masses can be made out throughout its entire length, but the outlines formed by these are sometimes very irregular. Figure 7 shows the appearance presented by a transverse section through the middle third of the fore-foot.

It may be remembered that, in addition to the main insertions of the suspensory ligament into the sesamoid bones and extensor tendons of the two digits, two very remarkable tendinous cords spring from its superficial surface and join the tendons of the perforatus. In my examination of the adult foot, I was led to the belief that these were structures foreign to the suspensory ligament proper, and derived from the dense fascia which invariably covers the intrinsic muscles of the foot. This fascia in the upper part of the foot apparently becomes incorporated with the surface of the suspensory ligament, whilst below it thickens laterally into the two rounded and free tendinous cords.

This view is strengthened by an examination of the sections through the foetal feet. Three points are brought out by these—(1) In the upper part of the foot, before the tendinous cords have separated, a distinct stratum may be noticed, forming the superficial part of the suspensory ligament. In many sections this layer is mapped off clearly from the subjacent part of the ligament by a little areolar tissue, in which one or two blood-vessels may be seen (fig. 4, *b*); (2) the muscular tissue never encroaches upon this layer; (3) below the point where the tendinous cords leave the ligament the fleshy masses reach both surfaces (figs. 5 and 7).

These facts, together with those which I have already adduced in the Report upon the Marsupialia,¹ warrant us in coming to the conclusion that the suspensory ligament of the ox has a twofold origin—partly muscular, partly fascial. That portion of the structure in relation to the fleshy masses is derived directly from the two flexores breves. The superficial part is developed, on the other hand, from the deep fascia which covers the intrinsic pedal muscles.

ROE-DEER (fig. 8).

The foetal roe-deer had apparently reached very nearly its full term of intra-uterine life. The antero-posterior diameter of the foot was three-eighths of an inch, the transverse diameter a quarter of an inch.

As I have not had an opportunity of examining the feet of an adult roe-deer, I am not in a position to contrast the foetal with the fully developed condition of the suspensory ligament in this animal. In the sections of the foetal pes four incomplete muscular rings may be noticed in the substance of the ligament. These rings are very small, and lie close to the metatarsal or deep surface of the structure. A great depth of tendinous tissue separates them from the superficial surface. As we have said, these rings are incomplete, but the breaks in the continuity of their outlines is not due to fat cells or degenerating muscular fibres, but to the replacement of the fleshy tissue by ligamentous tissue. The muscular fibres which are present are well developed and fully formed.

The only difference to be noticed in the sections through the fore-foot (fig. 8, *c*, *h*) consists in the greater quantity of the muscular tissue forming the fleshy rings, and the greater depth of the mass of ligamentous tissue (*d*) which separates these from the superficial surface of the ligament.

SAMBRE-DEER (fig. 9).

The sambre-deer could hardly be termed a foetus, seeing that it had been born alive, but had died a very short time after birth. In this case the suspensory ligaments were dissected out, hardened in a mixture of Müller's fluid and spirit, and then cut by means of Rutherford's microtome.

¹ *Loc. cit.*, p. 99.

The sections obtained in this manner show an exceedingly minute amount of muscular tissue in the substance of the ligament. In the ligament taken from the fore-foot there is, perhaps, a slightly greater quantity than in the case of the pes. It is arranged in both cases in the form of four delicate outlines placed side by side. The two lateral outlines are crescentic and large, and extend from one surface of the ligament to the other. The two central outlines are much smaller, circular or oval in figure, and are situated in the midst of the ligament, midway between its two surfaces. These muscular tracings are not altogether continuous, but are interrupted every here and there by intervals occupied by tendinous tissue. On examining these specimens by the high power of the microscope, it is seen that the fleshy fibres are almost invariably cut transversely, and that they lie in the intervals between the tendon bundles (fig. 9). So delicate is the tracing in many places, that it is formed by a single row of muscular fibres; in other situations there may be two, three, or even four such fibres abreast, and at certain points they are aggregated together in numbers varying from six up to ten. There is not a trace of fatty tissue, and the fleshy fibres are large, well developed, and without the least sign of degeneration. In one section, which shows some of the fibres in their long axis, they are seen to be beautifully striated.

A very striking character in this ligament is the enormous size of the nerves (*a* and *c*) when compared with the scanty amount of fleshy tissue with which they are associated. In one of the two circular central fleshy outlines in the ligament of the fore-foot there are two nerves, which, in transverse section, appear to occupy more space than all the muscular fibres composing the tracing taken together. Blood-vessels, in relation to the muscular fibres, are also to be seen (*b*).

With the exception of the slightly greater amount of muscular tissue in its midst, the only other feature which distinguishes the suspensory ligament of the fore-foot from that of the pes is that the central circular fleshy tracings are very much smaller.

I regret that I have not had an opportunity of investigating the structure of the suspensory ligament in the foetal sheep. I think it highly probable, however, that it would present characters similar to those observed in the sambar-deer. It is not likely

that we would find the muscular tissue in any greater quantity; most certainly we would find these presenting no signs of degeneration, and therefore uncontaminated by the presence of fat cells.

A study, therefore, of the foetal condition of the suspensory ligament of the fetlock is not without interest. It shows that in the embryo healthy muscular tissue is developed in its substance. This is present in proportionately greater quantity than in the adult. In the very early embryo of the ox, indeed, it constitutes fully half the bulk of the entire ligament. But, further, this muscular tissue retains its natural condition up to the time of birth. After birth, however, when the foot is called into play, and its requirements indicate the greater need in this structure of ligamentous than muscular tissue, a change begins. The fleshy fibres commence to degenerate, fat cells accumulate and fill up the gaps, so as to maintain the integrity of the outlines; and coincident with this there is a proliferation of the connective-tissue elements. The active change is confined entirely to the extra-uterine life of the animal, but a condition is produced in the parent which affects the offspring. It is an admirable instance of the slow progress made by morphological change, and of how processes of this nature are, as it were, thrown back a stage in the embryo. Provided that the external circumstances which originally instituted the process remain unaltered, we may consider that there are two conditions at work—*conservative* in the embryo, *progressive* in the adult; but the latter has the advantage, inasmuch as it is aided by the influence of heredity. From this, therefore, we may argue that in the course of time the transformation of the suspensory ligament will probably become complete, and that ultimately not a trace of muscular tissue will be found in its midst. It is very evident, however, that the fleshy fibres will be later of disappearing in the foetus than in the adult. The sambar-deer, the sheep, and the camel have made great advance towards this state.

It is evident also that the hind-foot in all the animals examined has approached nearer the completion of this process than the fore-foot. In every case the muscular fibres in the suspensory ligament are more plentiful in the fore-foot.

In my memoir published in the "Challenger" Reports,¹ I have stated my belief that the suspensory ligament of the adult camel has attained a completely ligamentous condition. A more recent examination of this structure under more advantageous circumstances has satisfied me that traces of muscular tissue are present in its substance. The arrangement of this tissue, however, is not very obvious in my specimens, as the sections were taken from a ligament which was in a very unfavourable state for microscopic examination.

In addition to the foregoing facts relating to the suspensory ligament of the fetlock, the sections through the foot of the foetal horse show some important points in connection with the development of the second and third dorsal interosseous muscles. In the adult horse these rudimentary muscles constitute (as I have previously pointed out) a clear and undoubted link in the soft parts between the modern monodactylous horse and its tridactylous ancestor. In the full-grown horse the second and third dorsal interossei are placed one upon either side of the suspensory ligament, and resemble in form the plantaris muscle in man. The fleshy bellies, however, very rarely exceed 2 or 2½ inches long. In the foetal horse these fleshy bellies are very largely developed, and can be traced in the transverse sections through the entire upper third of the metatarsus, and down even for a considerable distance into the middle third before they give place to their slender tendons (fig. 3, *b*, *d*; fig. 2, *c*, *h*; fig. 1, *f*, *m*). Both in respect, therefore, to the condition of these muscles and to the state of the suspensory ligament, the embryo of the horse approaches nearer the ancestral form than the adult.

I must not omit to express my thanks to Dr De Burgh Birch and Dr Arthur Thomson for the exact and careful manner in which they have executed the accompanying drawings. Fig. 4 is the work of Dr Thomson; the others, with the exception of fig. 9, were drawn by Dr Birch.

¹ *Loc. cit.*

EXPLANATION OF PLATE I.

Fig. 1. Transverse section through the pes of a foetal horse at the middle-third of the metatarsus. *a*, Middle metatarsal bone. *b*, Tendon of extensor digiti. *c*, Tendon of the so-called peroneus muscle. *d*, Great metatarsal artery. *e*, Rudimentary fourth metatarsal bone. *f*, Rudimentary third dorsal interosseous muscle. *g*, Digital vessels and nerve. *h*, Tendon of flexor perforatus. *i*, Tendon of flexor perforans. *k*, Digital vessels and nerves. *l*, Suspensory ligament of the fetlock. The two muscular tracings are represented in dark outline; the deep metatarsal vein is seen upon the deep aspect of the ligament. *m*, Rudimentary second dorsal interosseous muscle. The two dorsal interossei (*f* and *m*) are still observed to have a small amount of muscular tissue surrounding the slender tendon in which each terminates. *n*, Rudimentary second metatarsal bone.

Fig. 2. Transverse section through the upper third of the metatarsus of the pes of a foetal horse. Only those structures which are in immediate relation to the suspensory ligament are represented. *a*, Middle metatarsal bone. *b*, Second metatarsal bone. *c*, Second dorsal interosseous muscle. *d*, Deep layer of fascia covering the dorsal interossei and the suspensory ligament. *e*, Tendon of flexor perforatus. *f*, Tendon of flexor perforans. *g*, Digital nerve. *h*, Third dorsal interosseous muscle. The dorsal interossei (*c* and *h*) at this level are each observed to be composed of a fleshy belly of considerable size. The slender tendon is, in each case, seen to be imbedded in the midst of the fleshy tissue. *i*, Fourth metatarsal bone. *k*, The suspensory ligament with the two muscular tracings in dark outline.

Fig. 3. Transverse section through the upper part of the upper-third of the fore-foot of a foetal horse. Only those structures in relation to the suspensory ligament are represented. The posterior aspect of this figure is directed upwards. *a* and *e*, Lateral metatarsal bones (*i.e.*, 2nd and 4th). *b* and *d*, The large fleshy bellies of the second and third dorsal interosseous muscles. *c*, Suspensory ligament with the two irregular muscular tracings in its midst. *f*, Middle metatarsal bone.

Fig. 4. Transverse section through the middle of the metatarsus of a foetal ox of about four or five months. *a*, Suspensory ligament with the four muscular outlines represented by dark shading. *b*, Superficial stratum of the suspensory ligament derived from the deep fascia. In the upper third of the metatarsus the demarcation between these two strata is not so evident. At this stage the union between the two metatarsal bones is not nearly so close as in the adult; indeed, there is no bony union at all. The connection appears to be affected through the medium of the external fibrous layer of the periosteum only; each bone, therefore, has an independent and continuous covering of the deep cellular layer of the periosteum.

Fig. 5. Transverse section through the lower third of the suspensory ligament of the pes of a foetal ox of about four or five months. The

ligament is cut at the point where it divides into its four primary divisions. The two lateral divisions, *b* and *g*, have already separated; the two central divisions, *d* and *e*, are still connected. This drawing was taken from a specimen which had been stained with eosine; the muscular tissue is therefore represented by light shading, and the tendinous tissue by dark shading. *c*, *a*, and *f*, Strands of muscular tissue. *b*, *d*, *e*, and *g*, Tendinous tissue.

Fig. 6. Transverse section through the suspensory ligament of the pes of a very early foetal ox (*semi-diagrammatic*). The muscular tissue is represented by dark shading. *a*, Tendinous tissue of the suspensory ligament. *d*, The four muscular arches. *b*, Tendon of flexor perforans. *c*, Tendon of flexor perforatus. This tendon presents an appearance as if it also were traversed by muscular strands. This, however, is somewhat exaggerated in the drawing.

Fig. 7. Transverse section through the middle of the suspensory ligament of the fore-foot of a foetal ox of about four or five months. The muscular tissue is represented by light shading, the tendinous tissue by dark shading. *a*, Tendinous tissue. *b*, Muscular tissue; four outlines are observed,

Fig. 8. Transverse section through the middle of the metacarpus of the fore-foot of a foetal roe-deer. *a*, Extensor tendons. *b* and *i*, The united metacarpal bones. The union here is very close. *c* and *h*, Muscular stratum of the suspensory ligament. The four irregular muscular rings are observed in this. *d*, Great depth of tendinous tissue superficial to the muscular rings. *e*, Tendon of flexor perforans. *f*, Tendon of flexor perforatus. *g*, Digital vessels and nerve.

Fig. 9. Transverse section of suspensory ligament of the fore-foot of a very young sambre-deer under a high magnifying power. *a* and *c*, Nerves. *b*, Blood-vessel. *d*, Bundles of tendinous tissue. *e*, Transversely divided muscular fibres. The intervals between the groups of muscular fibres are occupied by small, evidently recently formed, tendon bundles.

ON THE ACTION OF INFUSED BEVERAGES ON
PEPTIC DIGESTION.¹ BY JAMES W. FRASER, M.D.
EDIN. (PLATE II.)

THE word "Peptic" is used in the title of this paper instead of the word "Gastric," to indicate that it is merely the chemical action of a fixed quantity of a beverage on the digestion of a fixed quantity of meat, by a fixed quantity of an artificial gastric juice, of a fixed composition, which is discussed, and that the actions of the beverages on the vital processes of digestion, such as the secretion of the gastric juice, its amount and quality, and on the muscular movements of the stomach, are by the nature of the experiment ignored.

In all these experiments all active factors (temperature, amounts of beverage, digestive fluid and meat, &c.) were kept invariable, except two, one with a known and controlled variability, and another, which varied with the known variable, and whose variations had to be ascertained.

In the first series of experiments the known variable was the kind of beverage used, and the unknown variable, the amount of dialysable organic matter produced by the digestion of the meat in the presence of this beverage. The experiments of this series were, for the sake of reference, called "Peptone Experiments."

In the second series the known variable was the same, but the unknown variable was the time taken for complete solution of the meat. These experiments were known as "Time Experiments."

In the third series the conditions were varied, and special to each experiment.

The beverages subjected to experiment were the following:— as examples of the teas (*i.e.*, beverages infused from prepared leaves), mixed tea, Chinese tea, Indian tea, green tea, mixed tea infused with water made alkaline with carbonate of soda, and

¹This essay is the substance of a thesis presented to the Medical Faculty of the University of Edinburgh, on graduation as M.D. in August 1883, and for which the author received a gold medal.

maté; of the coffees (*i.e.*, infusions of prepared berries), ordinary coffee, coffee with chicory (one part of chicory to four parts of coffee), and coffee, prepared by the Arab method as detailed by the traveller, W. G. Palgrave,¹ viz., the berries very slightly roasted and broken into fragments, and the infusion prepared by a very brief boiling with water; of the cocoas (gruels made from ground prepared seeds) the following examples were used, viz., Schweitzer's cocoatina to represent those cocoas from which the greater part of the fat has been extracted, Epps' cocoa as an example of those from which no fat has been extracted, and which contain starch and sugar; chocolate *menier*, guarana, and cocoa nibs.

Of these beverages five were taken as of more importance, viz., mixed tea, coffee, Schweitzer's cocoatina, Epps' cocoa, and chocolate, and to this list water was added to give an experiment for comparison. Each of these six beverages was subjected to experiment with eight kinds of food, viz., coagulated albumen (hard boiled white of egg), roast beef, boiled salt beef, roast lamb, boiled ham, roast fowl, fish (boiled haddock) and bread. The remaining beverages being less important, in this country at least, experiments with them were tried with white of egg only. Two experiments, one with white of egg and one with roast beef, were tried with undiluted digestive fluid, to ascertain the effect of the presence of water on digestion. In preparing the beverages care was taken to follow, as closely as possible, the ordinary culinary methods, and the most approved recipes were obtained. Each infusion was prepared by exactly the same method every time it was used.

The mixed tea, the coffee, and the Epps' cocoa, as typical of the three classes of beverages, were analysed by the following process, with the results shown in Table A:—To the filtered infusion subacetate of lead in solution was added, and the precipitate caused was filtered off; this precipitate consisted chiefly of a compound of lead and the tannic acid, or its homologue present in the beverage, and having been freed from lead by suspending in water and passing sulphuretted hydrogen and filtering, the clear solution was evaporated to dryness and weighed, the weight being shown in Table A as tannic acid. The filtrate from the lead tannate was freed from lead by

¹ Palgrave, *Central and Eastern Arabia*, 6th edition, pp. 36–37.

sulphuretted hydrogen filtered and evaporated to dryness, and weighed. The residue was treated with alcohol, which chiefly extracted the alkaloid, and the alcoholic solution having been filtered, was evaporated to dryness, leaving a crystalline residue, which was weighed, and the result in the table under the head of alkaloid expresses this weight. The weight of the alkaloid subtracted from the weight of the residue, before extraction with alcohol, gives the figure under the head of extractives.

The amount of volatile oil was estimated, but, as noted in the table, the process employed gave too large results.

The artificial gastric juice employed in all the experiments had the following composition :—

Benger's liquor pepticus,	.	.	.	:	20 c.c.
Dilute hydrochloric acid,	.	.	.	.	12 „
Distilled water, to	:	:	.	.	100 „

The dilute acid was the volumetric normal hydrochloric acid solution, containing 3.65 grms. of hydrochloric acid gas in 100 c.c., and was used in the proportion of 2 c.c. of the dilute acid in every 100 c.c. of digestive fluid, for each hour the experiment lasted. Thus prepared, the artificial gastric juice was a pale yellow acid fluid, of a specific gravity varying from 999.48 to 998.039; on carefully heating it became cloudy at 65° C., and gave a precipitate at 75° C., which, from its giving the Xanthoprotein reaction, was albumenoid in nature. All the experiments were performed almost exactly by the same process, which, for brevity, will be fully described once, and referred to afterwards as the Standard Process. In performing all the experiments the most rigid exactness was aimed at in every detail; most of the measures of quantity were made with the same piece of apparatus, and, where several similar pieces were necessary, the most exactly similar which could be obtained were used.

The Standard Process was as follows:—The beverages were prepared by the proper recipes and the digestive fluid made; 5 grms. of the meat to be subjected to experiment were weighed out; the meat was minced in a sausage machine before weighing, it was free from sinew or fat; the white of egg free from yolk, and the bread from crust. The weighed quantity of meat was

placed in a beaker, and to it were added 50 c.c. of digestive fluid, and 25 c.c. of the beverage under experiment. The beakers, for six experiments were usually performed simultaneously, were placed in a water bath, and maintained, by a small flame controlled by a mercury regulator, at a temperature of 37.7°C . In each beaker a tube was placed, the action of which will be understood from Plate II. fig. 1, in which A is the beaker, B the tube, and D a small tube communicating with B, and closed by a pinchcock C. The fluid was drawn up into the tube B by sucking out the air through D, when, on closing the pinchcock, the fluid was retained in B, and there cooling, caused convection currents in the direction of the arrows. These currents had, to some extent, the same action as the muscular movements of the stomach, in keeping up a continual circulation of the fluid through the meat. The tube from its action was called a "convection tube." Digestion was continued for six hours, in order that the results might be as large as possible, and at the end of this time the meat was more or less chymified. The chyme mass was filtered, and 25 c.c. of the filtered chyme were placed in a Graham's parchment paper dialyser, and this was hung in a saucer containing 100 c.c. of distilled water. It is evident that, as 75 c.c. of liquid were placed in a beaker, and 25 c.c. only were dialysed, the results of this dialysis must be multiplied by three to obtain the full results of the experiment. Dialysis was allowed to continue for twenty-four hours, and the 100 c.c. of water in the saucer having been withdrawn with a syphon, 100 c.c. more distilled water were placed in the saucer, and the process continued for twenty-four hours longer. At the end of this time the contents of the dialyser had quite lost their acid bitter taste, indicating an almost entire removal of peptones, while the water in the saucer had acquired that taste. The 200 c.c. of liquid were mixed, and the washings of the saucer and under side of the dialyser added to them, and the whole evaporated to dryness in a water-bath at a temperature of 100°C ., in the presence of 5 grms. of sodic chloride, to make the residue a more manageable substance. When this residue was dry it was cooled over sulphuric acid and weighed, the weight being called T. From this, a small portion was removed into a crucible and weighed, the weight being known as A. The crucible and its contents

were then placed in the hot closet of a water-bath, and kept there at a temperature of 100° C for eight hours, to drive off any last traces of moisture, cooled over sulphuric acid, and again weighed, the new weight being known as A'. To the contents of the crucible a small weighed quantity (about .15 gm.) of powdered chlorate of potash was added and the crucible covered and carefully heated till the organic matter was entirely oxidised. Its weight, after the subtraction of the weight of the crucible and of the chloride of potash, equivalent to the chlorate employed, was known as B, and it is evident that

$$\frac{T \times (A' - B)}{A}$$

represents the amount of organic matter in T, and

$$\frac{T \times (A' - B)}{A} \times 3$$

represents the amount of dialysable organic matter produced by the digestion of 5 grms. of meat with 50 c.c. of digestive fluid, in presence of 25 c.c. of beverage. In every case confirmatory combustions were performed.

It must be noticed that, by this process, no distinction is made between dialysable organic matters derived from the beverages and digestive fluid, and those derived from the meat. Therefore, that no error might occur from this, a set of experiments were performed by the Standard Process, with this exception, that no meat was used. The results of these digestions of the beverages are noted in Table B, and are there called "Factors." From this table it is seen that the factors vary, from that for digestive fluid (50 c.c.) digested in presence of water (25 c.c.), viz., .192 gm. to that for mixed tea .226 gm. and those for Epps' cocoa .53 gm. and for chocolate 1.059 gm. The largeness of these two last figures shows that the dialysable organic matters derived from the beverages might cause great errors in the results when meats were digested in presence of these beverages, and therefore, from the results of the formula

$$\frac{T \times (A' - B)}{A} \times 3,$$

obtained by the digestion of any meat in presence of a beverage, the factor of that beverage is deducted so as to obtain

a reliable result. 25 c.c. of the digested mixture of beverage and digestive fluid in the case of water, mixed tea, coffee, and Epps' cocoa respectively, was, in another experiment, dialysed and the 200 c.c. of liquid thus obtained, evaporated to small bulk, were analysed by the same process as was detailed above, as applied to the undigested beverage, with this exception, that to precipitate albumenoids before the subacetate of lead was used, absolute alcohol, with a drop of acetic acid, was added to the solution of dialysed matters, and the precipitate formed, filtered off, dried, and weighed. The results of these experiments multiplied by three to take in the whole 75 c.c. of mixed digestive fluid (50 c.c.) and beverage (25 c.c.) are shown in Table C. Comparing these results with those in Table A, it must be remembered that the latter express the amounts in 100 c.c. the former those in 25 c.c. In the case of tea and coffee, the albumenoids derived from the beverages were not sufficient to make up for those contained in the artificial gastric juice, the digestion of which was delayed by the action of the beverage, while cocoa yielded just enough to supply their place. The result given as acid under the head of water must have consisted of some substance, derived from the digestive fluid, not precipitated by alcohol but precipitated by the subacetate of lead. If this amount, which would most probably be about the same in each case, be subtracted from the results for tannic acid, under the heads of tea, coffee, and cocoa, it will be found that if these be reduced to percentages, the results for tea and coffee are pretty nearly the same as those in Table A but that for cocoa is more than double, showing that digestive fluid extracts more tannic acid from the suspended solids of cocoa than water can. A similar result is also seen under the head of extractives. The figures for alkaloids, owing probably to the presence in the digestive fluid of salts soluble in alcohol, are quite unreliable. Having thus examined the results of the digestion of the beverages alone, the results of their action on the digestion of meats come next to be studied, and these are embodied in Tables D and E. Table D gives the actual weights, obtained as above detailed, by the Standard Process, after the subtraction of the beverage factors, and in Table E, percentage results are given, obtained as follows:—the figures in the case

of each meat are multiplied by 100 and divided by the figure expressing the amount of the meat digested in presence of water, thus giving the percentage action of the beverages on digestion as compared with water as 100 per cent., for it is evident that the digestive power of a mixture of digestive fluid and a beverage varies directly as the amount of peptones produced from a quantity of meat, if that quantity be such as to leave some undigested at the end of the experiment, and if the quantities of meat, digestive fluid, and beverage, and all other active factors, be kept invariable in all experiments.

Examining Table D it is to be noted, (1) that the six experiments with each meat in the presence of water and of the five more important beverages respectively, were performed at one time, so that these six experiments were performed under precisely similar circumstances, and such sources of error, as possible variations in temperature or in the strength of the digestive fluid, are removed. There are one or two exceptions to this general rule, these are noted in Table D; (2) in the case of those beverages subjected to experiment with white of egg *only*, the factor experiments and the experiments with white of egg were performed at the same time, three beverages being used in each batch. The two experiments with undiluted digestive fluid were also performed separately.

There are some irregular results to be noticed in Table D before studying those more regular. Two of these are cases where minus results occur, that is, where the result, when meat was digested in presence of a beverage, was less than the beverage factor to be subtracted from it, and hence the result is a minus quantity; the two cases are white of egg and bread digested in presence of chocolate: the other irregular results are best noticed in Table E, where it is seen that there are four results above 100 per cent., white of egg and ham in presence of coffee, and fish in presence of cocoatina and of cocoa. There are various points in the process where error may have crept in, but all the measurings and weighings were conducted with the greatest care, and the temperature carefully regulated, and therefore these sources of error may be ignored. But the following causes may have operated:—(1) with thick beverages, like cocoa, the amount of suspended matter contained in the

25 c.c. of beverage used in the factor experiment may have been more or less than that contained in the 25 c.c. used in the experiments with meat, and thus error may have occurred; but this was guarded against by stirring the liquid before measuring out the 25 c.c.; (2) the suspended matters visibly clogged the action of the convection tube; (3) the dialyser may not have been wholly immersed, or may have touched the bottom of the saucer, or again it may have leaked, but all these accidents were carefully guarded against; (4) the sample chosen for combustion may have been poor in organic matter, or decrepitation in combustion may, in other cases, have caused the loss of some inorganic matter; but errors of this sort were guarded against by performing many combustions and by covering the crucible. The cause of the minus results appears to have been the clogging action of the suspended matters, and this would have been prevented in the stomach by the muscular action of its walls causing a more perfect mixing than the convection currents could effect. In the case of bread with chocolate, some charring occurred in the evaporation, and also assisted in producing this result. The causes of the results above 100 per cent., in the case of fish with cocoatina and with cocoa, are not evident; but reasons will be produced, in the case of coffee, to prove that it really does promote the digestion of white of egg, and presumably of ham.

On examining Table D, the actual results of digestion after deduction of the beverage factors, it is found that the largest result is that of salt beef digested in presence of water with 1.121 gram. or 22.42 per cent. of the meat used, and the next is fish with cocoatina with 1.107 gram. or 22.14 per cent. of the meat used, closely followed by salt beef with tea, with 1.063 gram. or 21.26 per cent. The smallest result, excluding the minus results, is egg with cocoa, with .164 gram. or 3.28 per cent. of the meat used, nearly approached by egg with Indian tea with .197 gram. or 3.94 per cent. The results are found in a more comprehensible form in Table E, where they are reduced to percentages, as compared with the result of the digestion of each meat in the presence of water as 100 per cent., and the average result with each beverage, deduced from all the experiments tried with it, is shown in a separate column. Of these average

results, the largest in the case of the five principal beverages is that with cocoatina with 89·96 per cent. and the others follow :—tea, 89·06 per cent. ; coffee, 88·79 per cent. ; Epps' cocoa, 76·05 per cent. ; and chocolate, 72·44 per cent. The nine less important beverages come in the following order :—tea with soda, 97 per cent. ; maté, 82·7 per cent. ; cocoa nibs, 78·8 per cent. ; Chinese tea, 72·8 per cent. ; Arab coffee, 67·97 per cent. ; coffee with chicory, 62·9 per cent. ; guarana, 57·14 per cent. ; green tea, 51·6 per cent. ; and Indian tea, 45·4 per cent. Where undiluted digestive fluid was used the average is 80·3 per cent.

From these averages it would seem that, of the five principal beverages, cocoatina has the least effect in retarding digestion, and chocolate the greatest ; but on examination it will be found that the high position of cocoatina depends on the fact, that, though it has no very high results, with one exception, yet on the other hand it has none very low, while tea, and more especially coffee, have some results very high (in the case of coffee two over 100 per cent.) but they also have some very low, which reduce their averages below that of cocoatina. The higher set of results, in the case of tea, contains the cases of roast beef, 96·4 per cent. ; salt beef, 94·8 per cent. ; ham, 95·98 per cent. ; and white of egg, 91·7 per cent. ; and the lower set—fowl, 66·73 per cent. ; lamb, 88·4 per cent. ; fish, 88·26 per cent. ; and bread, 89·23 per cent. With coffee, the higher set contains white of egg, 106·45 per cent. ; ham, 100·44 per cent. ; roast beef, 98·8 per cent. ; fish, 96·33 per cent. ; and salt beef, 93·4 per cent. ; and the lower set—bread, 58·27 per cent. ; lamb, 69·95 per cent. ; and fowl, 86·74 per cent. Now, the only case not in the same class in both series of results is fish ; excluding this, foods may be divided, with regard to the action of tea and coffee on their digestibility, into two classes, a class less affected in digestion, viz., white of egg, ham, salt beef, and roast beef ; and a class more affected, viz., lamb, fowl, and bread. It is to be observed that three of those in the former class, viz., egg, salt beef, and ham, are the usual occupants of the breakfast table, and this is the only meal at which custom seems to have sanctioned the admixture of animal food and infused beverages. Whether the selection of those meats, which experiment shows are least affected in digestion by infused beverages, has resulted

from a kind of survival of the fittest, it is impossible to say, but it is likely that some such action has been at work, for there is evidence that much less inconvenience is felt after the consumption of these meats at breakfast than when the others are used, and hence the most convenient have come to be the usual breakfast meats.

Comparing these two beverages, the comparison is in favour of coffee, so far as its action on this group of meats under the circumstances of the Standard Process is concerned, for coffee appears positively to assist the digestion of egg and ham, and its retarding effect on the digestion of roast beef is less than that of tea, though it is greater in the case of salt beef. In the lower set of results, coffee is seen to have less effect on the digestion of fowl than tea, but more on that of bread and lamb. In the case of bread, however, it is seen from the note to Table D, that the bread with coffee was one of the two experiments, which were charred in evaporation, and hence this result is smaller than it ought to have been. The action of both these beverages on the digestion of bread is to be noticed, but it must be remembered, that it is only their action on the digestion of the nitrogenised elements of bread, which is referred to, and that any action they may have on the digestion of the starchy constituents has yet to be investigated, and if these beverages interfere little with the digestion of the albumenoids of the breakfast meats, or even assist it, their action in retarding the digestion of the albumenoids of bread may be neglected. In the case of cocoatina, though its average is above that of tea or coffee, it will be found that the greater number of its individual results are below those of these two beverages; all its results being less than those with tea with the exception of fish, and all being less than those with coffee, except fish, lamb, and bread. The division of meats into two classes is less evident in the case of this beverage, the higher class here consisting of—fish, 139·77 per cent.; egg, 85·25 per cent.; roast beef, 88·09 per cent.; salt beef, 86·88 per cent.; ham, 88·96 per cent.; and bread, 87·22 per cent.; and the lower class—lamb, 77·04 per cent. and fowl 66·52 per cent. The higher set differs from that of coffee by containing bread, and from that of tea by containing bread and fish.

Epps' cocoa and chocolate throughout give smaller results than any of the above, and no such grouping, as in the cases of tea and coffee, can be detected. The higher class, in the case of Epps' cocoa, contains salt beef, 86·8 per cent. ; lamb, 83·35 per cent., and fish, 102·5 per cent.; and the lower class—roast beef, 78·2 per cent. ; ham, 70 per cent. ; bread, 73·76 per cent. ; and white of egg, 37·78 per cent. In the case of chocolate, the higher set contains fowl, 86·41 per cent. and fish, 88·38 per cent. ; and the lower—salt beef, 52·45 per cent. ; lamb, 62·71 per cent. ; and ham, 72·25 per cent. ; the minus results being omitted. These two groupings give no such intelligible results as are found with tea and coffee. Turning next to the nine less important beverages, only subjected to experiment with white of egg, the results vary from the tea with soda with 97 per cent. the highest percentage under 100 per cent. down to Indian tea with 45·4 per cent. The harsh flavour of Indian tea has gained for it a reputation for astringency, which is confirmed by this result. The addition of chicory appears to rob coffee of its power of assisting the digestion of white of egg, the result in this case being 62·9 per cent., and the same is true of coffee, when prepared by the Arab method, which gave 67·97 per cent. as its result.

The results of those experiments, in which the unknown variable was the time required for complete solution of a given quantity of white of egg, are shown in Tables F and G. The process followed was that of the standard experiment with these exceptions :—(1) the process was only carried on to the end of digestion, no dialysis being required ; (2) the quantity of meat used was only ·5 gm. instead of 5 grms : (3) the meat (white of egg) was placed in the convection tube, and retained there by a piece of coarse net tied over the end of the tube ; (4) to each beaker 1 c.c. of 3·65 per cent. solution of hydrochloric acid was added for every hour the experiment lasted, to make up for the acid used in digestion. The process was long, and from other engagements, had to be suspended for fifteen hours, during which the white of egg was exposed to the action of the digestive fluid and beverage at the temperature of the air, but as this period was the same in every case it does not vitiate the results. The actual times occupied in the complete digestion of the ·5 gm. of white of egg are shown in Table F. It is evident, that while

the amount of peptones, produced from a given weight of meat in a given time by a given quantity of a digestive mixture varies directly as the digestive power, on the other hand, the time required for complete solution of a given weight of meat by a given quantity of a digestive mixture varies inversely as the digestive power. Hence, if the results in Table F be reduced to percentages, to show their correspondence with the percentage figures in Table E, they must be inverted by the formula,—as (time per cent. required for complete solution) : 100 :: 100 : (percentage digestive power of the mixture). This has been done in the first column of Table G, in which the second column contains the percentage results with white of egg from Table E, and the third column the average result from the same Table. Between these three sets of figures the resemblance, in the case of tea, is very close, in that of coffee the resemblance is close between the two first figures, but the average figure differs from these; and in the cases of the other three beverages the resemblances are close enough to make this latter set of experiments confirmatory of the former. Had this resemblance between the two white of egg experiments in the case of coffee not occurred, the result of the former experiment, making it appear that coffee assisted the digestion of white of egg, would have been rejected as erroneous; but the similar results obtained by quite dissimilar processes make the action credible. The average for coffee is quite different, this resulting from the fact that coffee retards the digestion of most meats, only assisting that of white of egg and ham.

To sum up the results obtained by both processes; it has been shown:—(1) That all the infused beverages retard the digestion of all meats, which were subjected to experiment, with four exceptions, viz., white of egg and ham in presence of coffee, and fish in presence of cocoatina and of cocoa. (2) Under this general rule, some subdivisions must be noticed, viz., that tea and coffee have much less action on the meats usually eaten at breakfast (egg, salt beef, and ham) than on other meats; that coffee has less action on these meats as a rule than tea; that cocoatina has more retarding action than either tea or coffee, and the same subdivision into a class of breakfast meats and a class of others is noticed but less markedly than with tea and coffee;

and that cocoa and chocolate retard the digestion of meats more than any of the former beverages, and no subdivision into two classes of meats is to be noticed in their case.

Having examined the effects produced on peptic digestion by these beverages, the causes of the effects come next to be considered, and, as a first step towards this, the chemical reactions of the beverages with various organic substances were ascertained. It was found that tea produced a precipitate when added to a solution of egg albumen, and also with solutions of gelatine, syntonin, and peptones, and with the artificial gastric juice. This last precipitate was not dissolved by dilute hydrochloric acid, as was found by Mr Brownen¹ to be the case with the precipitate produced by tannic acid in an artificial gastric juice. Coffee, with the same solutions as were used in the reactions with tea, gave no precipitate with the gelatine or syntonin solutions, nor with the artificial gastric juice, and only slight precipitates with albumen and peptones. Filtered Epps' cocoa gave precipitates with all the solutions, viz., albumen, gelatine, syntonin, peptones, and with the artificial gastric juice. A mixture of 50 c.c. of the digestive fluid and 25 c.c. of water, digested together for six hours at a temperature of 37·7° C., gave a slight precipitate when added to a solution of egg albumen, thus agreeing with normal gastric juice. Of the beverages mixed with the digestive fluid in the same proportions, and digested for the same time at the same temperature, tea gave a slight precipitate with albumen solution, and none with gelatine or any other of the solutions, thus showing that the tannic acid of the tea had been robbed of its power of precipitating gelatine by the peptic ferment; contrary to the result stated by Mr Brownen,¹ viz., that the action of the pancreatic ferment was required to change the tannic into gallic acid, and so cause it to cease to precipitate gelatine. The digested solutions of coffee and of cocoa gave no precipitates with any of these solutions, more than could be attributed to the digestive fluid.

The examination of the possible causes which might assist in producing the action of the beverages on digestion, comes next to be considered.

¹ "On the Digestion of Drugs," *Pharmaceutical Journal*, Aug. 16, 1882, and *Lancet*, 1882, vol. ii. p. 492.

The first possible cause is, that the precipitate formed by the action of the tea or cocoa on the gastric juice might carry down, entangled with it, some of the pepsin, which might not be entirely redissolved during digestion. As coffee produces no precipitate with the digestive fluid, this cause does not apply to the "coffees." That some pepsin is carried down in the precipitate, and is partly redissolved during digestion, is shown by experiments, the results of which are found in Table H and I. In the experiments, the beverages, after being mixed with the digestive fluid, were filtered, and the digestion was performed with the filtered mixture, by the Standard Process. An experiment without meat was performed to obtain a factor, and its result is shown in Table H, where it is found that the factor for tea filtered after mixing with digestive fluid, is .001 gram. less than the factor under the Standard Process. This is a very small amount, and that it consisted of pepsin filtered off with the precipitate, and which could not, therefore, be redissolved to act on the meat, is shown by the figure in Table I, where the result of the digestion of 5 grms. of white of egg, with the filtered mixture of tea and digestive fluid, is seen to be only .34 gram. instead of .398 gram., which was the result where the precipitate was allowed to remain during digestion (Table D). The results in Table H and I with coffee are seen to be the same as with the unfiltered mixture, because no precipitate forms in this case; and those with cocoa, as regards this cause, are masked by the removal of the suspended matters of the cocoa as well as the precipitate.

The next possible causes are, the coagulation of any albumenoids of the meats, which may have escaped coagulation during cooking, and the tanning action of the beverage on the gelatinous bands, resulting from the cooking of the perimiscium of the meat, causing these bands to contract and press on the albumenoids of the meat retarding their digestion, in much the same way as a thread tied firmly round a piece of fibrin retards its digestion by preventing it swelling. The albumenoids are coagulated by tea, coffee, and cocoa, but gelatine is coagulated by tea and cocoa only, and, therefore, this latter action can only take place with these two kinds of beverages. The results of experiments bearing on the action of these causes are

seen in Table J, in which the following five experiments are embodied :—In the first experiment 5 grms. of minced roast beef were digested with 50 c.c. of digestive fluid and 25 c.c. of water by the Standard Process, and it may be noted that for some reason the results in this case are much smaller than in the experiment performed by precisely the same process, the result of which is shown in Table D. In the second experiment of the five, 5 grms. of the same beef were soaked for six hours in 25 c.c. of water at a temperature of 37.7° C., the water was then strained off and the soaked meat digested according to the Standard Process with 25 c.c. of water and 50 c.c. of digestive fluid. In the third experiment tea was used for the soaking instead of the water, and the meat, after straining off the tea, was digested with 25 c.c. of water and 50 c.c. of digestive fluid. In the fourth case coffee took the place of tea, and in the fifth filtered cocoa. At the end of the soaking, the meat soaked in water and that soaked in cocoa were pale and swollen, and the liquids opalescent, that soaked in coffee was brown, and the liquid opalescent, and that soaked in tea was brown, shrunken, and leathery, and the liquid very thick indeed. On looking at the table the results seem contradictory, but it will be found possible to reconcile them with those already observed. Here the meats soaked in tea and in cocoa give larger results than those soaked in water and in coffee; in the case of cocoa larger than those with ordinary digestion. Now all the albumenoids soluble in water, and therefore, most easily acted on in digestion, would be removed in the cases of water and coffee by the preliminary soaking, and only those coagulated by cooking would remain to be acted on by the digestive fluid, while with tea the tannic acid would coagulate and harden the outer layers of the meat, and so protect the soluble albumenoids of the inner layers from the action of the soaking liquid. Of course this hardening would also protect them from the action of the gastric juice, but not so perfectly as their entire removal in the soaking fluid. With cocoa this effect would also take place, but the largeness of this result depends more on the amount of sugar contained in the soaking liquid, some of which would remain in the meat when the cocoa was poured off, and be dissolved during digestion. The percentage result with tea as a soaking fluid is smaller than

that when tea was used by the Standard Process (Table E), viz., 83.72 per cent. instead of 96.4 per cent., this depending on the fact that when the beef was soaked in the tea, its albumenoids and gelatine were exposed to the full activity of the tannic acid, none having been removed in precipitating the albumenoids of the digestive fluid.

The fourth cause to be considered is the possible action of the volatile oils of the beverages in delaying digestion. To ascertain if this cause took any part in producing the effect, the volatile oil of 25 c.c. of each beverage was distilled off in a fractional distillation apparatus, and made up to 25 c.c. with distilled water, and these were used as the beverages of three experiments otherwise performed by the Standard Process, the meat used being white of egg. Factor experiments were also performed without meat, and the results of the digestion of the white of egg after subtraction of the factors are found in Table K.

No precipitate formed on mixing the solutions of the volatile oils and digestive fluid, but as digestion went on a precipitate formed in all three cases. It was found by experiment that the volatile oil gave no precipitate with solutions of either syntonin or peptones, and therefore, this precipitate must have been of the nature of that somewhat indefinite body, the dyspeptone of Meissner, and any action of the volatile oils must have been merely in favouring its production. The figures in Table K are all small, owing probably in part to the formation of this precipitate, the decrease being greatest in the case of coffee, viz., from .434 grm. the result with water as the beverage, to .234 grm., and least in that of cocoa, viz., from .434 grm. to .286 grm.

The fifth possible cause of the action of the beverages is, that the alkaloids may delay digestion. To put this to the test, the alkaloid of 25 c.c. of each beverage, having been prepared by the process detailed above, was dissolved each in 25 c.c. of water, and these solutions used as the beverages of three experiments performed by the Standard Process, the meat being white of egg. Factor experiments were also performed. The results of the digestion of white of egg, after subtraction of the factors are found in Table L, and it is seen that in the presence of theobromine alone does the result fall below .434 grm. (the

result obtained when water was the beverage) being in this case .391 grm.; while in the presence of theine and of caffeine, the results are above .434 grm., viz., .437 grm. and .484 grm. respectively. Nor are these latter figures surprising, when it is remembered that theine and caffeine are only two names for the same alkaloid—methyl-theobromine.

The sixth possible cause is the precipitation by the tannic acid or its homologue in the beverage of the peptones and syntonin as formed. It has been seen that undigested tea and cocoa precipitate syntonin, and all the typical beverages precipitate peptones, but after digestion they do not; therefore it is evident that unless the beverage is thoroughly digested before syntonin or peptones are formed, or unless all the tannic acid is used up in other actions, the syntonin and peptones will be thrown down as they are formed. The experiments, the results of which are embodied in Table M, were performed each with the tannic acid of 25 c.c. of each beverage, prepared by the process detailed above, and dissolved in 25 c.c. of water, these solutions being used as the beverages of three experiments otherwise performed by the Standard Process, with white of egg for the meat. Factor experiments were also performed, and their results subtracted from those of the experiments with meat. A precipitate occurred on mixing the solution of tannic acid and the digestive fluid, not only in the cases of tea and cocoa but also in that of coffee, and the precipitate seemed rather to increase than diminish during digestion. From the table it is seen that only in the case of the tannic acid of tea is any marked reduction produced, showing what was to be expected from the less active nature of the acid in coffee and cocoa, viz., a less interference with digestion.¹ It is to be noticed that this result depends on a different action from that where beef was soaked in each of the beverages, for here albumen, coagulated by heat and therefore, insusceptible of further coagulation by the tannic acid, was used, and hence the only way in which the reduction in the results could be brought about, was either by the precipitate from the tannic acid carrying down some of the pepsin entangled with it (first possible cause), or from the

¹ The tannic acid of tea is stated by Rochleder to be querci-tannic acid, the same as that present in oak bark.

precipitation of the syntonin and peptones as formed ; and that this latter was the true cause is supported by the fact that, in the case of tea, in which the greatest effect was produced, the precipitate visibly increased as digestion proceeded, but in the other cases the precipitate did not increase so much, and, therefore, in these the entanglement of pepsin in previously formed precipitates may have had the greatest effect.

To further test the action of the precipitation of syntonin as formed, the following experiment was performed :—A solution of syntonin and a digestive fluid of double strength were prepared. To 25 c.c. of this digestive fluid 25 c.c. of the syntonin solution were added ; this would give a solution of an unknown quantity of syntonin in 50 c.c. of the usual digestive fluid. Four such quantities were prepared, each containing an unknown but equal quantity of syntonin. To the first 25 c.c. of water were added, to the second 25 c.c. of tea, to the third 25 c.c. of coffee, and to the fourth 25 c.c. of cocoa. On the addition of the tea to its special quantity a dense precipitate occurred. The Standard Process was then followed out with the results, after deducting the factors, shown in Table N, which show a very great reduction in all cases with beverages, from the result with water, but greatest in that of tea, where, from the weakness of the syntonin solution, and the almost complete precipitation of the syntonin by the tea, very little dialysable organic matter was produced.

The seventh possible cause applies only to those beverages containing a considerable amount of albumenoid matters, and is that the accumulation of peptones and the action of undigested albumenoids in precipitating pepsin, as shown by Von Wittich, may hinder digestion. That such an accumulation has this effect has long been known, and is shown in the results in Table D, where white of egg and beef were digested with undiluted gastric juice, but no other experiments bearing on its action were made, and it is on purely theoretical grounds that it is here put forward.

The eighth and last possible cause applies only to the beverages which contain much suspended matter, and depends on their retarding the convection currents and also gathering round the meat and protecting it from the digestive fluid. That such

an action did occur is seen from Tables H and I, where the results of a factor experiment and one with white of egg, performed by the Standard Process, but after filtering the mixture of cocoa and digestive fluid, are shown. In the factor experiment a reduction in the factor is seen as compared with that for unfiltered cocoa, that in the case of the filtered beverage being .412 grm., that for the unfiltered .53 grm., showing that the digestive fluid extracted .118 grm. of dialysable organic matter from the suspended solids of 25 c.c. of cocoa. The results of the experiment with white of egg (Table I) is .547 grm. as compared with .164 grm. when unfiltered cocoa was used, showing a very large balance in favour of the filtered cocoa, which appears even to assist digestion. This clogging action of the suspended solids can, however, only take place in experiments such as these, for in the stomach the powerful mixing action of the muscular movements of its walls would prevent any such stagnation, and it is probable that, had the convection currents in these experiments been only strong enough to overcome the clogging, the thick beverages of the cocoa class would have occupied a more favourable position.

Summing up the causes determining these actions of the beverages, it may be said that tea, taken as the type of all the "teas," reduces peptic digestion chiefly by its tannic acid, which acts, by coagulating the albumenoids, which have escaped the action of cooking, by tanning the gelatinous parts of the meat, and causing them to contract and press on the albumenoids, by removing the pepsin itself entangled in the precipitates formed, and by precipitating syntonin and peptones as formed. The volatile oil of tea also has some action in reducing digestion, and the alkaloid seems to favour the digestion of white of egg, but its action is masked by the opposite action of the tannic acid.

The action of coffee appears to be in the direction of favouring the digestion of ham and white of egg, and this must depend on the power of the alkaloid to assist proteolytic action; but coffee, as a rule, retards the digestion of meats, in which it is a type of the "coffees," and this must be caused by the caffeo-tannic acid and by the volatile oil.

The action of cocoa is, in some respects, intermediate between those of coffee and of tea. The action of its acid is slightly

greater than that of caffeo-tannic acid, but that of the volatile oil is less than that of the volatile oils of tea and coffee. But the suspended matters of the cocoas give rise to the causes, which produce the most important results in these experiments, viz., the accumulation of peptones and the clogging action of the suspended solids, but neither of these would act in the case of digestion in the stomach, for the peptones would be absorbed as quickly as they were formed and the clogging would be prevented by the stomach movements.

Having thus examined the total action of infused beverages on peptic digestion, and the apparent causes of this action, experiments were performed with the view of ascertaining the effect of the presence of water and of each of the three principal beverages on certain constituents of the chyme resulting from the digestion of white of egg. The experiments were performed by the Standard Process, following it only as far as the end of the stage of digestion, when the chyme was filtered and the filtrate analysed. As a preliminary step, the acid of the digestive fluid was estimated by volumetric analysis, and was found in this case to be equivalent to .424 grm. hydrochloric acid per cent. The acid remaining in the filtered chyme was similarly estimated, allowance being made for the dilution of the digestive fluid with one half its bulk of beverage, with the results shown in Table O. The 50 c.c. of digestive fluid used in each of these experiments would contain .212 grm. of hydrochloric acid, and it is found that, by the process of digestion in the presence of water and of coffee, this had been reduced to .18 grm. and in that of cocoa to .172 grm. while in that of tea the reduction was less, .195 grm. remaining. No allowance is made for the concentration of the fluids during the six hours' exposure to the air at a temperature of 37.7° C., which would cause the evaporation of some water,¹ and therefore these figures are greater than they should be. It is seen that coffee has no more effect on the consumption of acid than water, and cocoa increases the consumption on account of the amount of suspended solids containing peptonisable albumenoids it contains, while tea reduces the consumption of acid by reducing the amount of syntonin produced.

¹ Hydrochloric acid weaker than a 20 per cent. solution loses water by evaporation till that strength is attained.

Another measured quantity of the same filtered chyme in each of the four cases was concentrated to small bulk on the water bath and absolute alcohol, with a drop of acetic acid added to it to precipitate the albumenoids; the precipitate was filtered off, washed with alcohol, dried, and weighed, and the washings and filtrate in each case having been mixed, were evaporated to dryness and the residue weighed, the weights being given in the table. The albumenoids are seen to be greatest in quantity in the case of tea, and least in that of water, while coffee and cocoa take an intermediate place, which may be partly accounted for by the fact that the soluble albumenoids of tea are slightly greater than those of coffee (see Table C), and that the clogging action of cocoa in digestion is such that the peptones derived from its albumenoids only suffice to supply the place of those not produced from the egg. The residue, after evaporation of the filtrate from the precipitated albumenoids, contained the salts of the beverages and digestive fluid and those extracted from the egg, but it also contained nitrogenised organic matter, as was shown by its giving the Xanthoprotein reaction with nitric acid. These residues were tested for leucine and tyrosine, which it was thought might be present, though the action of the pancreatic ferment is usually said to be necessary for their production in the digestion of albumenoids. Tyrosine gives the most delicate reactions, and therefore, it was alone sought for. The tests used were Hoffman's (mercuric nitrate and nitric acid) test, said by Hoppe Seyler to be able to detect $\frac{1}{1000}$ part of tyrosine in a liquid, and Piria's (sulphuric acid and ferric chloride) test. With the residues in the cases of tea and water, no results beyond the Xanthoprotein reaction occurred with Hoffman's test, and none at all with Piria's. In the case of coffee the Xanthoprotein yellow was turned to orange by the pink of Hoffman's reaction, and the yellow of the ferric chloride was turned greenish through the development of the blue of Piria's reaction. In the case of cocoa Hoffman's test showed traces of tyrosine but Piria's gave no reaction. Summing up this part it may be said that, (1) tea reduces the consumption of acid in digestion, coffee is neutral, and cocoa increases the consumption; (2) coffee, in assisting the digestion of white of egg, carries on the action of the digestive ferment, so that not only peptones but

tyrosine also are produced, cocoa also has this effect, though not to such a high degree as coffee, and tea has no such effect.

There is another clinically familiar item in the effects of infused beverages, viz., the amount of flatulence often resulting from their use, and the amount of this effect was put to the experimental test as follows :—five small flasks were taken, and into each, meat, beverage, and digestive fluid, in the proportions of the Standard Process, were introduced ; the flasks were then tightly corked, and through each cork a small tube, bent to form a manometer, and containing mercury, was passed. In the first flask the meat was roast beef, the beverage water ; in the second roast beef, and in the third ham, both with tea ; in the fourth beef with coffee, and in the fifth beef with cocoa, but on account of leakage through the cork, this last was a failure.

On the flasks being heated in the water bath, the manometers rose till they reached a height indicating the vapour tension of water at that temperature (37.7° C.) found by experiment to be about 57 millimetres, and then any increase in the height of the mercury must have been due to the production of gas in the flasks. All the corks leaked a little, as will be seen from Table P, where the heights of the manometers taken every hour are recorded ; any fall of the mercury would be caused by this leakage, and any rise, supposing the temperature to be kept constant, would be caused by the flatus evolved. Therefore, by taking in each case the sum of the rises of the manometer, an approximation would be obtained to the amount of flatus produced. For example, in the case of water, the mercury was just stationary to the end of the second hour, and then fell to the end of the third, rose 7 millimetres at the end of the fourth hour, and then fell steadily to the end of the experiment. Here the whole rise is this 7 millimetres, and this indicates the amount of flatus produced ; and, proceeding in the same way, the figures in Table Q are obtained, which show that coffee and water have the same effect in producing flatus from the digestion of roast beef, and tea increases its production, but when salt meat is used, such as ham, less flatus is produced even when tea is present. This result would probably have been greater had not leakage occurred, but it is quite in accordance with experience, that less flatus is produced during

the digestion of salt meat in the presence of tea, than if fresh meat be used.

Portions of the chymified mass from the flasks containing beef and water, tea, and cocoa respectively, were removed, and, having been mounted as microscopic objects in glycerine, were examined with a power of 300 diameters. The sketches in Plate II. fig. 2 were made from these preparations.

The beef digested in presence of water showed the transverse striæ of the muscular fibres faintly, the fibres breaking up into discs and fibrillæ, and in some places the empty sarcolemma tubes alone remained. The muscle nuclei were also seen, in most cases, as dark linear bodies, but in some places granular. Some were seen floating free, the so-called "nuclein" of the true nuclei being insoluble in digestive fluid, and set free by the peptonisation of the protoplasm surrounding the true nuclei. The vessels and nerves could be faintly recognised in places.

In the case of beef digested in presence of tea, the transverse striæ of the muscular fibres were more distinct than in the case of that digested in presence of water, and division of the fibres into discs and fibrillæ was more rare, and nowhere was a perfectly empty sarcolemma tube to be seen. The muscle nuclei were distinctly granular, and fewer were found floating free. The appearance of the nuclei, as consisting of a linear series of granules, becoming smaller towards the ends, points to the beverage having tanned the protoplasmic matter surrounding the true nuclei, and this, by its shrinking, having constricted the nuclein in places, producing the beaded appearance of the nuclei. The nerves and vessels also were distinctly visible.

In the case of cocoa, the transverse striæ were very distinct, but longitudinal striation and division into discs and fibrillæ were rare, and very few empty sarcolemma tubes were to be seen. The nuclei were granular, and but few were seen free. The specimen contained much granular matter from the beverage, and the nerves and vessels were very distinct. The conclusions to be drawn from the microscopic examination of the chyme are—(1) that tea delays digestion of muscular fibre by coagulating the albumenoid matter of the sarcous substance, as shown by the preservation of the transverse striæ of the muscular fibres; (2) that the action of the tannic acid on the fibrous tissue surround-

ing the nerves and vessels of the meat, preserves them from digestion; (3) that the conclusions in the case of cocoa are similar, but as the tannic acid is weaker in this beverage than in tea, the protective action of the suspended solids is required to account for the action of the digestive fluid on the meat, being almost as little in the presence of this beverage as in that of tea. All the foregoing experiments have been tried with beverages as prepared by the culinary recipes with water, but not in the state in which they are usually drunk; and to ascertain the effect in modifying the action of the beverages on digestion, of the additions of milk and sugar, customary in this country at any rate, the following experiments were performed:—The process followed was that of the standard experiments, except that to the 25 c.c. of beverage 5 c.c. of new milk and 1.25 gm. of white sugar were added, these having been ascertained to be very nearly the usual proportions. The caseine of the milk rapidly coagulated on the addition of the digestive fluid, and in twenty minutes after the commencement of digestion the liquid was clear, but contained floating flakes of caseine.

Factor experiments were performed, and one with 25 c.c. of water with 5 c.c. of milk and 1.25 gm. of sugar. The factor results (Table R) are all seen to be high, as was to be expected from the easily digestible nature of the milk and the high diffusive power of the sugar, but that for tea is less than that for water, with these additions, because of the action of the tea interfering with the digestion of the caseine. The results in Table S of the digestion of white of egg in presence of the beverages with these additions, are very interesting. The result with coffee, making it appear that the addition of milk and sugar reverses the action of coffee on the digestion of white of egg, may be fallacious. The effect of these additions to tea is greatly to reduce its retarding action, and to increase the amount of dialysable organic matter produced from the 5 grms. of white of egg, after subtraction of the factor for tea with milk and sugar, from .398 gm. to .426 gm., or from 91.7 per cent. to 98.15 per cent., as compared with the results when white of egg was digested in the presence of water without milk or sugar. The result for cocoa with milk and sugar is just what would be expected. The suspended matter of the cocoa has been seen to be the most

active agent in reducing digestion in its presence, and, if to the suspended matter of the beverage a suspended coagulum of caseine be added, it is not wonderful that the amount of white of egg peptonised is still further reduced. This action would most probably not occur in the stomach, where the more powerful mixing would prevent the clogging action of the caseine. Therefore it is safe to say, that, if milk and sugar be added to the infused beverages, tea has much less action in retarding digestion, and if these additions have no effect in reducing the retarding action of the other two beverages on digestion, they at any rate increase their nutritive value.

The chief points shown by these experiments may be recapitulated here, it being premised that all must be understood to apply to the experiments as performed by the Standard Process, or the modifications of it above described:—

(1.) All infused beverages retard the peptic digestion of albumenoid food-stuffs with the four exceptions mentioned above, viz., ham and white of egg with coffee, and fish with cocoatina and with cocoa.

(2.) The digestion of the meats ordinarily used at breakfast, viz., ham, egg, and salt beef, is less retarded by the action of tea or coffee than that of other meats, and the same is true of roast beef; with cocoatina a somewhat similar grouping occurs, but with regard to the other beverages of the cocoa class, no such division into a group of breakfast meats, and a group of those less suitable for breakfast use, has been observed.

(3.) That this retarding action is less as a rule with coffee than with tea, and less with either than with the beverages of the cocoa order.

(4.) That the retardation is caused (*a*) in the case of “teas,” by the tannic acid assisted by the volatile oil, the former precipitating the uncoagulated albumenoids of the food, and the syntonin and peptones as formed, tanning the gelatinous constituents of the meats, and removing some of the pepsin by entangling it with these precipitates, and the latter retarding the action of the pepsin. The alkaloid of tea appears to assist digestion, but its action is masked by that of the tannic acid and volatile oil. (*b*) In the case of “coffee,” the caffeo-tannic acid and volatile oil retard digestion, and the alkaloid assists it;

and, therefore, in the cases where this beverage assists digestion, the alkaloid must be the active agent in producing the result, and in the cases where digestion is retarded, the caffeo-tannic acid and the volatile oil. (c) In the case of the cocoas, the tannic acid, volatile oil, and alkaloid all assist in retarding digestion, but under the conditions of the Standard Process, the clogging action of the suspended matters is the most potent factor.

(5.) In retarding the consumption of acid during digestion tea has the greatest effect, coffee has no more effect than water, and cocoa increases the consumption.

(6.) Coffee and cocoa cause the peptic digestion of albumenoids to pass on through the stage of peptones to the formation of leucine and tyrosine.

(7.) Tea acts on the digestion of fresh meat so as to increase the production of flatus, but has no such effect with salt meat, and coffee has no more effect than water.

(8.) The addition of cream and sugar to the beverages reduces the retarding action of tea on digestion, but increases that of cocoa; and coffee appears to have its action reversed by these additions, but this result is doubtful.

From these experimental results the following practical conclusions as to the use of these beverages may be drawn, but it must again be clearly stated that only those factors producing digestive action, which are represented in the Standard Process, viz., the action of the acid and ferment in producing syntonin and peptones, are considered, and that any effects of the beverages on the secretion and quality of the gastric juice, and on any vital process in the stomach, are ignored, though in one or two instances, conclusions may be drawn with regard to these also.

It has been seen that, if at any meal containing albumenoid matters one of these beverages be drunk instead of water, a reduction in the amount of peptones produced will occur, and, if the proportions of beverage, digestive fluid, and meat, and the other conditions correspond with those of the standard experiment, the reduction will be in the proportion of the percentage results in Table E, as compared with what would have been peptonised had water only been drunk. Now it is evident that a person making such a meal, accompanied by one of the infused

beverages, must either be content to suffer this loss, or he must eat more food to make up for it. Therefore, infused beverages should never be partaken of at a meal consisting largely of albumenoid matter, by either the very poor, to whom every grain of animal food is of importance from its cost, or by the dyspeptic, who cannot afford to have his delicate stomach irritated by undigested food. Indeed, the only class of people who can with benefit take infused beverages along with animal food, are those who habitually eat too much meat, which would, if digested and absorbed into the blood, induce gout or some renal complaint by causing too great a strain on the kidneys in its elimination, but which, if precipitated by the tannic acid of the beverage, and rendered insoluble, will be thrown off unabsorbed.

Considering first the case of the very poor: Sir Lyon Playfair gives the following as a "subsistence diet," and quotes a London sempstress as an example of the class of persons living on it:—

Nitrogenous matter,	.	.	2.33 oz. or 65.95 grms.
Fat,	.	.	0.84 „ 23.8 „
Carbohydrates,	.	.	11.69 „ 331.4 „

the food being reckoned as dry solids. This diet, excluding fats, would be represented by—

Bread,	.	.	19.3 oz. or 550 grms.
Meat,	.	.	10.5 „ 300 „

reckoned as they appear as articles of diet, and containing water.

It is quite safe to premise that this woman will drink a great quantity of tea of an inferior quality.

By calculation, it has been found that the infused beverages consumed in the United Kingdom in the year 1881–82 amounted to 35.3 gallons per head of the population, or to about .75 pint per diem.

Assuming that she did not exceed this .75 pint in a day, and applying the percentage results in Table E to the consideration of the subject, this amount, mixed with twice its bulk of digestive fluid in the stomach, would be equivalent to reducing the peptones produced from 85 grms. of her bread, to the same amount, as if only 75.8 grms. had been eaten with water as the beverage. The peptones of 85 grms. of beef would similarly be reduced to what they would have been had only 81.9 grms. of

beef been eaten, and in the case of 85 grms. of fish to the same as if only 75 grms. had been eaten, with water as the beverage. Tea is asserted by Lehmann to reduce tissue waste, but Dr E. Smith, from his experiments, asserts that it increases it. Taking Lehmann's view as correct, the less requirements of the system, through the use of infused beverages, may compensate for the less amount of peptones produced from the meat. If this compensation does not occur, manifestly the person who drinks infused beverages with a meal will require more food than the one who does not, but, even if it does occur, it would be more economical to take the infused beverage on an empty stomach, and then, when meal time came, less food would be required and there would be no loss of albumenoid matter.

The cocoas yield more nourishment than the coffees or teas, and it may be believed that, owing to the mixing action of the movements of the stomach, they retard digestion as little as any infused beverage, and, therefore, they are the most suitable for the poor.

The coffees, as a rule, retard digestion, and the cases, where they appear to assist it, are really as disadvantageous as the others, for they carry some of the albumenoids through the stage of peptones to that of leucine and tyrosine, and thus force-producing matter is lost to the system.

In the case of dyspepsia, besides the action of the beverages in precipitating albumenoids, and placing them beyond the reach of the digestive fluid, there are other actions to be considered. If the dyspepsia be of the flatulent order, tea should be avoided when unsalted animal food is eaten, on account of the increase of flatus following their digestion together, and, if this action is alone to be considered, coffee is the best beverage.

If the dyspepsia is of the acid form, from over-acidity of the gastric juice or its over-secretion, tea, from its power of reducing the consumption of the acid, is the worst beverage, coffee is neutral, and cocoa would be best from its increasing the consumption of acid; but if there is any tendency to the lactic acid fermentation, cocoa should be avoided from the sugar it contains, for though Dr Garrod states,¹ that in America sugar is used to lessen acidity, he is careful to point out that this applies only to

¹"Lumleian Lectures on Uric Acid," *Lancet*, 1883, vol. i. p. 582.

"pure sugar," and not to "sweetened fruits and such-like substances," under which head cocoa may be reckoned.

Therefore, in cases of flatulent dyspepsia, if coffee does not agree, all infused beverages should be interdicted when unsalted meat is eaten. In cases of acidity from over-secretion of the gastric juice, cocoa is the best beverage, and in cases of fermentation acidity, if coffee does not suit, all infused beverages should again be forbidden.

For those who habitually eat too much animal food, tea is the best beverage, as it appears to act on some of the albumenoids so as to entirely protect them from peptic digestion, and to cause them to be rejected unabsorbed, while coffee, in the cases where it increases digestive activity, forms leucine and tyrosine, which have still to be eliminated by the kidney.

Having considered their disadvantages, some of the redeeming features of infused beverages may be noticed. Considered from the point of view of peptic digestion, infused beverages, especially when taken with milk and sugar, are the means of conveying no small amount of nourishment into the system, for, from the tables, the amount of dialysable organic matter derived from the digestion of 25 c.c. of chocolate is 1.059 grm., while 25 c.c. of tea with 5 c.c. of milk and 1.25 grm. of sugar yields 1.345 grm., and cocoa under the same conditions, 1.677 grm. The first of these three figures is double that derived from the digestion of 5 grms. of white of egg for six hours in presence of water, and the last more than trebles this amount. These quantities, derived from 25 c.c. of beverage, show that a considerable quantity of nourishment is contained in a cupful.

To these points in their favour must be added the action of some infused beverages, (coffee and cocoa), in assisting digestion in certain cases. These figures also point to the fact that the beverages should never be drunk as mere watery infusions, but milk and sugar should always be added both to increase their nutritive value, and in the case of tea, to reduce undesirable actions. As regards the times of using infused beverages, manifestly they should not be used at meals which consist largely of animal food. This requirement has come to be very generally followed out, except among the poorest classes, and

with their exception most people only make this undesirable combination at breakfast, and, as already seen, the usual breakfast meats are those least acted on in digestion by tea or coffee. Coffee has been seen to have less deleterious effect than tea on the digestion of these meats, and it should therefore be used at breakfast, when not rendered unsuitable in other ways.

The meal of tea, when arranged in the Yorkshire fashion, is merely a repetition of breakfast with the addition of many cakes and sweets, which do not add to its digestibility. If "tea" be made a meal, the model of breakfast should be followed, or the solid part of the meal should consist entirely of bread and other vegetable food-stuffs, so as to have as little albumenoid matter as possible to be acted on.

The cup of coffee after dinner may have some effect on secretion, or may be useful to neutralise the effects of other potations, but, from its action on peptic digestion, it has little to recommend it, and the same applies in a much higher degree to the cup of tea coming about an hour later, just when the process of peptonisation is at its height, and there is the largest amount of nitrogenised matter in solution to be precipitated by it.

The ladies have a meal which has been much maligned, viz., 5 o'clock tea, but all things considered, this is perhaps just the best time for the enjoyment of a beverage which has the effect of retarding the digestion of any nitrogenised matter it comes in contact with, for early lunch has had full time to be chymified and to have disappeared from the stomach, and so to have got beyond the reach of the tannic acid of the tea, while the time intervening before dinner will suffice for the removal of the slight amount of solid matter said to be eaten at "Kettledrum." Again, this is just the time, after the afternoon's occupations are over, when the stimulant action of the tea will be useful to carry the energies on to the time of their full refreshment at dinner.

The worst habit of all, and one which cannot be too highly condemned, is that of continually drinking tea, whether the stomach be full or empty, which leads to imperfect digestion of whatever food the tea may meet, and may lay the foundation of serious gastric troubles.

APPENDIX.

TABLE A.

Percentage compositions of the three principal beverages.

	Tea.	Coffee.	Cocoa. ¹
	Per cent.	Per cent.	Per cent.
Tannic acid, . . .	·247	·252	·267
Alkaloid, . . .	·189	} ·551 {	1·46 ²
Extractives, . . .	·306		·595
Total solids, . . .	·742	·803	2·322
Volatile oil, ³ . . .	·32	·31	·41
Water, . . .	98·938	98·887	97·268

¹ Filtered. ² Impure, containing sugar. ³ Impure, containing water.

TABLE B.

Results of digestion of 50 c.c. of digestive fluid, alone, with 25 c.c. of water, and with 25 c.c. of each beverage.

	Factors.
	Grms.
Digestive fluid undiluted, . . .	·192
„ with water, . . .	·192
„ with mixed tea, . . .	·226
„ with Chinese tea, . . .	·272
„ with Indian tea, . . .	·318
„ with green tea, . . .	·413
„ with tea with soda, . . .	·259
„ with maté . . .	·246
„ with coffee, . . .	·269
„ with coffee with chicory, . . .	·336
„ with Arab coffee, . . .	·297
„ with cocoatina, . . .	·237
„ with cocoa, . . .	·53
„ with chocolate, . . .	1·059
„ with cocoa nibs, . . .	·297
„ with guarana, . . .	·374

TABLE C.

Analysis of results of digestion of beverages.

	Water.	Tea.	Coffee.	Cocoa.
	Grms.	Grms.	Grms.	Grms.
Proteids, . . .	·015	·009	·006	·015
Tannic acid, . . .	·048	·114	·102	·219
Alkaloid, . . .	·219	·189	·18	·279
Extractives, salts, &c., . . .	·018	·09	·096	·2

TABLE F.
Results of time experiments.

Digestive fluid	with water,	10 hrs. 48 min.
"	with mixed tea,	12 " 8 "
"	with coffee,	9 " 23 "
"	with cocoatina,	15 " ... "
"	with cocoa,	12 " 8 "
"	with chocolate,	14 " 33 "

TABLE G.
Percentage digestive powers of mixtures of digestive fluid and beverages deduced, A, from time experiments; B, from peptone experiments with white of egg; C, from average of peptone experiments.

	A.	B.	C.
	Per cent.	Per cent.	Per cent.
Digestive fluid with water,	100	100	100
" with mixed tea,	89.26	91.7	89.06
" with coffee,	115.02	106.45	88.79
" with cocoatina,	72.04	85.25	89.96
" with cocoa,	89.26	87.78	76.05
" with chocolate,	76.33	...	72.44

TABLE H.
Factors for beverages filtered after mixing with digestive fluid and then digested.

Tea mixed, . . . . .	.225 grms.
Coffee, . . . . .	.263 "
Cocoa, . . . . .	.412 "

TABLE I.
Results of digestion of 5 grms. white of egg with 50 c.c. of digestive fluid and 25 c.c. of beverage, filtered after mixing.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water, . . . . .	.434	100
Mixed tea, . . . . .	.34	78.34
Coffee, . . . . .	.462	106.45
Cocoa, . . . . .	.547	126.03

TABLE J.

Results of digestion of 5 grms. of beef with and without soaking in water and beverages.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Digested without soaking,	·891	100
„ after soaking in water	·618	69·36
„ after soaking in mixed tea, . . .	·746	83·72
„ after soaking in coffee,	·651	73·06
„ after soaking in cocoa,	1·002	112·45

TABLE K.

Results of digestion of 5 grms. of white of egg in presence of water, alone, and with the volatile oils of 25 c.c. of beverages.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water alone,	·434	100
„ with volatile oil of tea,	·266	61·29
„ with volatile oil of coffee,	·234	53·91
„ with volatile oil of cocoa,	·286	65·89

TABLE L.

Results of digestion of 5 grms. white of egg in presence of water, alone, and with the alkaloids of 25 c.c. of beverage.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water alone,	·434	100
„ with theine,	·437	100·63
„ with caffeine,	·484	111·52
„ with theobromine,	·391	90·09

TABLE M.

Results of digestion of 5 grms. of white of egg in presence of water, alone, and with the tannic acid or its homologue of 25 c.c. of beverage.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water alone,	·434	100
„ with tannic acid tea,	·339	78·11
„ with caffeo-tannic acid,	·42	96·77
„ with tannic acid cocoa,	·418	96·31

TABLE N.

Digestion of syntonin in presence of water, and of the three principal beverages.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water,	·1206	100
Mixed tea,	·0176	14·6
Coffee,	·021	17·4
Cocoa,	·0615	50·9

TABLE O.

Results of digestion of 5 grms. white of egg in presence of water and beverages.

	Water.	Tea.	Coffee.	Cocoa.
	Grms.	Grms.	Grms.	Grms.
Acid,	·18	·195	·18	·172
Albumenoids,	·2	·247	·22	·22
Residue from albumenoids, .	·49	·58	·6	·78

TABLE P.

Pressure (in millimetres) registered hourly in the experiments on the production of flatus.

	Water.	Tea.	Tea.	Coffee.
	Beef.	Beef.	Ham.	Beef.
1st hour	Mm. 52	Mm. 37	Mm. ...	Mm. 61
2nd „	52	40	57	57
3rd „	48	39	54	57
4th „	55	44	59	64
5th „	54	43	52	59
6th „	49	43	50	64

TABLE Q.

Amounts of flatus produced (expressed in millimetres pressure).

Water.	Tea.	Tea.	Coffee.
Beef.	Beef.	Ham.	Beef.
7 mm.	8 mm.	5 mm.	7 mm.

TABLE R.

Factors of 25 c.c. of beverage, with 5 c.c. of milk and 1.25 grms. of sugar digested with 50 c.c. of digestive fluid.

	Factors.
	Grms.
Water,	1.345
Tea,	1.275
Coffee,	1.413
Cocoa,	1.677

TABLE S.

Results of digestion of 5 grms. of white of egg in presence of water, and of the beverages with milk and sugar.

	Actual Weights.	Percentages.
	Grms.	Per cent.
Water without milk, . . . . .	.434	100
Tea with milk and sugar, . . . . .	.426	98.15
Coffee with milk and sugar, . . . . .	.237	54.6
Cocoa with milk and sugar, . . . . .	.04	9.2

ON A METHOD OF PROMOTING MACERATION
FOR ANATOMICAL MUSEUMS BY ARTIFICIAL
SUMMER TEMPERATURE. By JOHN STRUTHERS,
M.D., *Professor of Anatomy in the University of Aberdeen.*

THOSE who are engaged in museum making must have felt the inconvenience of being able to macerate only in warm weather; aware at the same time, that boiling, or any approach to it, would ruin the bones. It occurred to me that an arrangement by which a sufficient and safe temperature could be maintained throughout the year would enable me not only to get on faster with the formation of the anatomical museum, but to have the skeletons more nicely cleaned. As I have not found such means used, but warm-weather maceration only, at the museums of London or elsewhere, the following notes of my method may prove useful to others:—

After considering various plans by which the macerating water might be maintained at a tepid temperature, I fixed on the method by hot water circulating through galvanised iron pipes placed within the macerating tanks.

The Tanks.—I have two tanks, made of wood, one 8 feet the other 4 feet in length, both 3 feet in breadth and 2 feet in height, inside measurements. The larger is calculated as sufficient to take in the largest whale's rib. The lesser one proved large enough to take in the bones of my large Indian elephant, except the head, and is the tank I generally use. Thickness of sides and ends 3 inches, of bottom $2\frac{1}{2}$ inches. Common red fir-wood will do, but is not so secure against possible leaks as yellow pine. Any intelligent joiner should know how to fit up such a tank securely, but I may mention some particulars.

The planks are all 8 inches in breadth, fitted to each other by double ploughing and feather. Those of the bottom are, in addition, joined together by a $\frac{1}{2}$ -inch thick iron rod passing through them at the middle, from end to end of the tank, secured by the usual screw-nut and short iron plate. The ends of the tanks are "checked" $\frac{1}{2}$ -inch deep into the sides. The

parts of the sides which project, for 3 inches, beyond the ends are bolted together immediately outside each end of the tank by two $\frac{1}{2}$ -inch thick iron rods, secured by screw-nuts resting on a narrow iron plate which runs nearly the whole height of the tank.

In fitting on the bottom there was the usual groove filled with white lead before the bolting. The main-bolts are one at each end, two at each side of the lesser, three at each side of the greater tank. These pass through the planks from bottom to top, secured below the bottom by nuts resting on an iron plate, above concealed by wooden plugs so as to leave a uniform level top. The rag-bolts are two at each end, and, along the sides, one for each plank. They pass from below the bottom into the lowest plank of the walls.

There might be no harm in a little leakage, but these tanks, thus fitted, have been in use for many years, and are quite water-tight. When not in use a little cold water is kept in them.

A cover is useful both to keep in heat and keep out dust. It is made of $\frac{1}{2}$ -inch thick planks joined by two cross bars, and fits exactly the outer edge of the tank. It is better loose than hinged, and is easily lifted off or pushed aside. That of the larger tank is in two pieces.

The tanks are raised on stands 2 feet high, so as to be 2 feet above the level of the boiler. They should in any case be high enough from the floor to admit of the tank being emptied through the bottom. Any form of rough strong stand, with uprights, frame, and stays, will do.

Filling the Tanks.—Mine stand against the wall, end to end, with interval of 4 feet, so that there is free access in front and at the ends. The supply-water pipe (ordinary lead pipe, $\frac{3}{4}$ -inch bore) runs along the wall, and gives one cock for the smaller and two cocks for the larger tank. Having two for the larger tank, one towards each end, is useful in cleaning out. The cocks are at 6 inches above the tanks, so as not to interfere with the shifting of the lid. A hinged lid would interfere with them and with the gas on the wall. I have also a hot-water supply pipe, the same as the cold one; a branch from the hot-water pipe which supplies the dissecting-room basins. When the hot water

is not needed there, it may be turned on to fill the tank, but this small economy is not of much use. The water in the tank might be kept warm in this way by a constant inflow and outflow, but this would be an expensive way, and it would not be easy by it to diffuse the heat, especially in the lower stratum.

Emptying the Tanks.—The tank should be a little off the level, an inch is enough, and the emptying tap placed at the front corner of the lower end. The escape opening should be in the bottom. It is not possible to empty a tank by a side opening placed even as low as can be, without a great deal of mopping. The opening should be covered by a convex “rose.” When mine had at first the usual depressed rose, the apertures became obstructed. The tap is opened and closed by a cock placed below the tank, worked by a hand lever. The floor of the room is of concrete, laid so as to slope to a central drain aperture, enabling us to keep the floor clean by playing water on it with a hose. Instead of discharging on the floor, a temporary waste-pipe might conduct to a drain aperture. As running off the water of maceration is apt to raise a considerable odour, we used to do it at night in the old rooms, and we send a good run of clean water after it to flush the drains.

Heating the Water in the Tanks.—In the old rooms the tanks and entire heating apparatus were fitted up together in an out-house. In the new anatomical buildings the room for maceration is placed in the underground flat, and the boiler stands in the adjoining general furnace-room. This is convenient for chimney and coals, and avoids dust in the macerating room. The boiler, a common “saddle” boiler, is built on a level with the floor, the ashpit excavated to a depth of 2 feet. The pipes, ordinary low-pressure iron water pipe, 1-inch bore, travel along the wall and so that the return pipe has always a gentle descent towards the boiler, pierce the partition wall, and run along the wall of the macerating room about on a level with the bottom of the tanks. My flow-pipe is single, and bifurcates between the tanks, giving a branch to each, a stopcock on each branch enabling us to use the tanks either separately or together. This little economy of pipe partly depends on the position of the tanks; but it would probably be better to have the circulation through each tank independent all the way, with a stopcock on each.

The pipes enter and leave the tanks at their lower and neighbouring ends; the flow-pipe entering near the back corner, the return pipe emerging near the front corner. Within the tank the pipe makes several turns, so as to give six lines of pipe along the bottom of each tank. The pipes are not quite in contact with the bottom, allowing a finger to pass between. In my first arrangement I had only one pipe round the walls of the tank, 4 inches from the bottom; but, besides being insufficient to give the requisite heat, this left a stratum of cold water at the bottom. The number of turns, of course, may be more or less according to the temperature wished. I reckoned that six lines of pipe would give a temperature of 100° Fahr., and find that it does so readily. The attendant lowers the fire when the temperature reaches 95°. Every part of the pipes in contact with the water in the tank is carefully galvanised so as to prevent rust, which would stain the bones. To prevent the bones being overheated by contact with the pipes, a light wooden grating is placed over the pipes, which sinks readily when it is wet and weighted by the bones. This grating may be tied down on the pipes before the tank is filled.

Supply Cistern and Pipe.—The cistern (18 inches \times 14 \times 8), with ball-cock, stands in the macerating room about 2 feet higher than the top of the tanks, but may stand anywhere if at a sufficient height. The supply-pipe from it may join either of the return pipes at any stage, as it is the boiler that is to be supplied. *Discharge Pipe.*—This, of gas-pipe metal, $\frac{3}{4}$ -inch bore, should join at the highest part of the circulation, as its use is to let off any air or steam in the pipe. Either it should pierce the raised end of the tank to join one of the loops, or one of the loops may pierce the tank so as to allow the junction to be made outside. Each tank should have a discharge pipe. The discharge pipe should be carried up so as to be higher than the supply cistern, and may then bend down and discharge into a vessel with waste-pipe, or, as I have it, into the supply cistern itself.

Heating by Water Pipes.—The method of heating by what used to be known as “Perkins’ Patent” would give a more active circulation and higher heating power. It is, in my experience, by far the best method of heating lecture-rooms and

laboratories, and is now in use in all the other rooms of the anatomical department; but for heating the macerating water I preferred to have the simple low-pressure heating boiler and pipes above described, as being quite sufficient, less costly to put in, and more simple to work.

Heating by Steam Pipes.—When I applied the hot-water pipe method to the above purpose I was familiar with that method of heating and therefore adopted it, but were it to do again I would prefer to try the method of heating the water by steam as less expensive, more simple, and likely to be fully as efficient. For that there would be required an ordinary steam boiler, supplied by a branch from the nearest water pipe, but no supply cistern or discharge pipe, except the ordinary blow-off pipe at the boiler. To prevent water passing to the boiler from the tank, the boiler would require to stand higher than the water in the tank, or the pipe, at some stage of its course, to be carried higher than the tank. By this method the tank need not be raised from the floor farther than to allow of the working of the tap below it. Less and more simply arranged pipe within the tank would suffice, galvanised, and with the perforations for the escape of the steam into the macerating water.

Macerating in the Furnace-Room.—Conduction by air will not sufficiently heat a large body of water in the room, but jars placed near the furnaces may be sufficiently and conveniently warmed in that way. In my furnace-room I have a broad shelf of iron grating fixed on the wall, just above the three Perkins' furnaces which heat the anatomical department, and in jars placed on the shelf such objects as skulls, hands and feet, and the parts of the smaller animals, are conveniently macerated. Each jar can be ticketted, and, by having a number of small jars on a tray, each digit, &c., marked right and left, can be kept separate so as easily to make certain that every phalanx and carpal and tarsal bone, and every sesamoid, will be in its right place in the skeleton. In the case of a less familiar animal I keep one foot and hand for a time only partially macerated to guide us in articulating the other side correctly. Skeletons in museums are not always to be relied on in that respect. In macerating in the furnace-room the jars should have covers to keep out the coal dust.

ON THE WAX-LIKE DISEASE OF THE HEART. By D.
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Anatomy (Sir Erasmus Wilson Chair), Aberdeen University.*
(PLATE III.)

THE heart is usually not considered to be a situation in which the wax-like disease is commonly localised. From the careful examination of the heart in instances of general waxy disease of late, I have found that it is present in one or all the chambers in nearly every severe case, and sometimes when the affection is limited to only a few organs.

The first record of the lesion is apparently that given by Virchow (*Archiv.*, Bd. xi. S. 188) as occurring in a woman who suffered from Bright's disease, and where there was wax-like implication of other organs as well. Since then a few papers on the subject have been published in foreign journals by Eberth (Virchow's *Archiv.*, Bd. lxxx. S. 160), Heschl. (*Wiener. Med. Wochenschrift*, No. 2, 1876), and Ziegler (not published, but mentioned in MacAlister's translation of his *Lehrbuch der Path. Anat.*, p. 90). The description given by these of the condition is more or less incomplete, in so far as the exact locality and nature of the disease are not clearly indicated. Eberth's description is certainly the best with which I am familiar, and, although in general it is corroborative of what I have myself seen, there are some points to which he has not drawn special attention, and which seem to me to be of considerable importance.

As regards the naked-eye appearances, the most of the cases that have been noted are those in which there was an evident gross lesion. In Virchow's case the walls of the heart were thickened, pale-brown coloured, and somewhat translucent. In Ziegler's case there were great numbers of large waxy masses in the endo- and pericardia, with a smaller number of similar dépôts in the myocardium. Along with these waxy masses there seems also to have been a certain amount of cirrhosis of the myocardium.

Although a macroscopic lesion of this kind may be present

occasionally, yet far more commonly there is nothing to indicate the presence of the wax-like substance within the organ. The only appearance which, so far as I have seen, is at all indicative of wax-like disease of the heart, is a faint milkiness of the endocardium occurring in small patches. The auricles are more frequently and more severely affected than the ventricles, and I think the right auricle more than the left. The wall of the chamber is usually not thickened, in fact it is often attenuated along with a similar wasting of the other muscular tissues throughout the body. Its colour is pale brown, due to the anæmia which exists throughout the organ. The abnormal appearances, however, are so slight that attention is generally not drawn to the heart as a site of the wax-like infiltration. The only means by which its presence can be clearly demonstrated to the naked eye is by the application of solution of iodine to the endocardium. The brown stain, which is characteristic of the presence of the wax-like material, is at once brought out in the endocardium. It is not universal or diffuse, but occurs in little round or irregular patches about half a line to a line in breadth. The muscular substance sometimes shows some brown points, but at others these are not visible, either from there not being any of the wax-like substance in the myocardium or from the stain being obscured by the brown colour of the fibre. I am inclined to believe, however, that it is more frequently present in the endo- than in the myocardium. The pericardium in such cases usually does not give any iodine reaction. Virchow mentions that it occasionally does, but amyloid disease of the heart wall is by no means necessarily associated with similar disease of this membrane. In the same way the epicardium is generally free from the disease. The muscular fibre and the endocardium are the tissues which, practically speaking, form its special seats, and in this there is a marked coincidence with the disease as it occurs in the small arteries—the inner and muscular coats being, as is well known, the usual localities in which it is present.

The drawings accompanying this communication show the usual appearances characteristic of the lesion. The preparations were stained in methyl-aniline and mounted in Farrant's solution. This means of staining is by far the most demonstra-

tive, the position of the foreign substance being mapped out as seen in fig. 1, in an absolutely diagrammatic manner. It is much more reliable for microscopic purposes than iodine or iodine and sulphuric acid. With these last two reagents it is almost impossible to obtain a clear view of the minute changes, and hence discrepancies in the description of how the disease invades the tissues have in all probability been perpetrated.

A low power view of a cross section of the wall of a waxy auricle is given in fig. 1. The endocardium is represented at *g*, and the epicardium with its œdematous sub-epicardial tissue (*b*) at *a*. Between the two is the waxy infiltrated myocardium. The methyl-aniline, as is generally known, gives a pink reaction with the wax-like substance, and the extent of the disease in this, which is an ordinary specimen, will be evident from the figure.

Within the substance of the endocardium are seen several waxy deposits. They are separated by considerable intervals, and, as is usually the case in other organs and tissues, the wax-like substance is deposited in the form of little irregularly-shaped masses. When looked at with a magnifying power of 300 diameters the homogenous waxy material is seen to have infiltrated the substance of the fibrous tissue of the membrane, and to have pushed the fibres aside. In course of time the fibres become surrounded by the new substance, and, when so, they look almost as if they had become converted into it. I cannot find, however, any distinct evidence of this neither in the endocardium nor in other parts of the heart wall. In all the preparations that I have examined of this disease the methyl-aniline stain gives in the earliest stages a diffuse faint pink colouration of the fibrous tissue, as if a fluid (albuminous) had soaked into it, and had subsequently become insoluble. One can easily understand, in view of this theory of the disease, how parts not originally waxy might become soaked with the albuminous fluid before it underwent the amyloid transformation, and how, under such circumstances, a slight diffuse staining of these might result from the application of methyl-aniline solution. I have never seen any swelling of the fibrous tissues such as would naturally be expected were there a true transformation of the fibrous tissue into the wax-like substance. As regards the

question of its being poured out in the vicinity of a blood-vessel, I cannot say that I have noticed that a sub-endocardial vessel was in any way connected with the deposits in the endocardium itself. No doubt, round the sub-endocardial vessels there is usually a large quantity of waxy infiltration, but I could not recognise the continuity of this with the deposits of the foreign material in the endocardium proper. The latter appeared to be quite isolated.

The sub-endocardial fibrous tissue, uniting the endocardium to the muscular part of the wall, contained many waxy deposits, and, as just said, they were formed round the blood-vessels in this neighbourhood. The small arteries as usual contained most of it. Their middle coat was thickened, homogeneous, and gave a bright reaction, while the interspaces of the adventitia also contained much of the new substance. Here, as in the endocardium, I could not detect any transformation of the fibrous tissues into the amyloid, but in the commencement of the disease merely what seemed to be a soaking of them with a product which at one time had been soluble, followed later on by a complete infiltration and distension of their interspaces.

The myocardium is usually the chief seat of the deposit. Here it is present, as seen in fig. 1, in great quantity, and, as in other parts, is deposited in little clumps or patches (*f*). These masses are situated either within a fasciculus of muscular fibres (figs. 2, 3, and 4) or around the small arteries running in the perimysium externum. The former is by far the commoner of the two sites. Between the perimysium internum and the muscular fibril, there is in the heart, in place of the sarcolemma, a small space, and so far as I have been able to make out, it is into this space that the waxlike infiltration is first poured. The capillaries between the fibre are evidently the source of it, but very soon the space around them becomes filled with the homogeneous glassy substance, forming an investment fibre (figs. 3 and 4). A similar statement is made by Eberth (*loc. cit.*). On longitudinal section of a muscular fasciculus, long stripes of pink-stained waxy tissue can be seen lying between the individual fibrils (fig. 4, *a*), and when the fasciculus is examined in transverse section, each fibril is seen to be enveloped in a sheath of the same (fig. 3, *b*). At first there is merely a slight pink somewhat diffuse stain of the

interfibrillar space, but soon the space enlarges from the great quantity of new substance within it, so that adjacent fibrils become compressed. In course of time the fibre undergoes atrophy, as shown in fig. 3, where the fibrils have shrunk and become irregular in outline. They undergo rapid diminution in size, and finally break down into a quantity of granular matter, which appears ultimately to be absorbed. As the fibres shrink, the waxy material becomes relatively more abundant, until finally large masses of the latter, without any trace of muscular tissue, may be formed. The perimysium externum appears to limit the size of each little mass, so that they do not tend to coalesce.

The muscular fibres during this time usually give a slate-blue reaction, with methyl-aniline, as shown in fig. 3, *a*; that is to say, they do not become waxy. I have occasionally, however, seen a slight pink or purple reaction within them, as in fig. 2. This, I think, however, is due to some of the amyloid having soaked into them rather than to their having become transformed into it. My reasons for supposing this to be the case are, that one never sees the fibrils swell up into the homogeneous obscure-glass-like tissue, and that usually, even where the fasciculus is far advanced in the disease, they give only the slate-blue colour with methyl-aniline. I have frequently seen the same pink stain produced in tissue elements which do not become primarily waxy in other organs, more particularly where a waxy vessel runs say close to an epithelial surface. The waxy vessel seems to diffuse the morbid material all round, and thus a general stain may be produced. In the same way it is, I hold that the occasional pinkish colour of the muscular fibre is to be accounted for. The capillaries between the fibrils pour out the foreign substance, and this in some instances soaks into the tissues around, which are not of themselves primarily waxy. The only truly retrogressive change which the muscular fibres undergo, appears to be that of atrophy. Nor does this seem to be exceptional in the case of the heart muscle. Ziegler (Virchow's *Archiv.*, Bd. lxxv. S. 273) describes a case of waxy tumour disease in the tongue in which the ends of the muscular fibres penetrating the tumours underwent the same attenuation and atrophy. In many other situations I have seen similar appearances, both in striped and unstriped muscle. In fact, in all organs it would appear that

the tissue elements merely succumb by a process of atrophy to the pressure exerted upon them by the infiltrating waxy masses. Notably is this seen in the waxy liver and kidney.

The invasion of the muscular fasciculus takes place partially. As seen in fig. 2, several small masses form at different points in the bundle. These enlarge, and, in course of time, may run together and become diffuse.

The small arteries between the fasciculi are almost all waxy (fig. 3, *c*). The infiltration of their coats is sometimes partial, at others complete. The small veins in some situations (fig. 1, *c*) also become waxy, and a great many of the capillaries besides those of the actual muscular fasciculi have a waxy deposit in their walls and around them. The eminently vascular distribution of the disease here, as in other organs, is thus borne out, other tissues, which also contain the new substance, being, according to my experience, secondarily infiltrated.

The epicardium and subepicardial tissue, as shown in fig. 1 (*a* and *h*), are usually free from waxy disease, and the nerves contained in these (one of which is shown in the subepicardial tissue) do not give any pink reaction. In the case related by Virchow (*Archiv. Bd. xi. S. 188*), he mentions that there were tumour-like masses on the cardiac, sacral, and uterine nerves, which gave the brown reaction with iodine, and he infers therefrom that they were also probably waxy. These are, however, not a usual concomitant of ordinary cases of waxy disease of the heart.

DESCRIPTION OF PLATE III.

Fig. 1. Section through a waxy right auricle. $\times 50$ diam. stained with methyl-aniline. *a*, epicardium; *b*, oedematous subepicardial tissue, with a section of a cardiac nerve in it; *c*, a waxy vein in the myocardium; *d*, waxy myocardium; *e*, middle sized artery, not waxy; *f*, a mass of waxy substance in a muscular fasciculus; *g*, endocardium, with waxy masses in it.

Fig. 2. Trans. sect. of muscular fasciculus of heart $\times 300$ diam. (methyl. aniline). *a*, non-waxy muscular fibrils seen on cross section, others obliquely cut; *b*, two waxy masses lying among the fibrils.

Fig. 3. Several isolated muscular bundles cut across and surrounded with waxy substance $\times 300$ diam. (methyl-aniline). *a*, atrophied muscular fibrils; *b*, waxy substance; *c*, small waxy artery.

Fig. 4. Long. sect. of muscular fasciculus, $\times 300$ diam. (methyl-aniline). *a*, waxy material surrounding fibrils; *b*, atrophied muscular fibrils.

ON THE RELATIONS OF THE DORSAL ARTERY OF
THE FOOT TO THE CUNEIFORM BONES. By
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Hospital.*

THE usual course of the dorsal artery of the foot may be indicated by a line drawn from the front of the ankle, midway between the malleoli, to the back of the first interosseous space.

This line will be found to cross in succession the fore part of the astragalus, the scaphoid, the middle, and also a small portion of the internal cuneiform bones.

In contemplating these facts it appeared to me strange that anatomists, in their descriptions of this artery, should have made no mention of the *middle* cuneiform bone, as one of its most constant posterior relations. In all the descriptions I have read with the view of ascertaining this point, I find that the internal cuneiform bone is always either named or clearly implied, but, as far as I have learned, the middle cuneiform is never even noticed.

It will be seen on dissection that this artery usually takes a fairly straight course between the points named; sometimes, however, it curves outwards, as if pulled aside by its tarsal and metatarsal branches, and in these instances its relations are necessarily somewhat altered. But I find when the direction of the artery is quite normal it invariably crosses the broad base of the middle cuneiform, and merely touches (but not always) the fore and outer part of the internal cuneiform, just where it grasps the inner articular facet on the base of the second metatarsal bone. There is usually a slight scooping out of the pointed end of the cuneiform bone at this spot, and the artery most commonly occupies this little valley before dipping into the first interosseous space on its way to the sole of the foot.

After its passage over the middle cuneiform its deep relations are not constant. It may rest on the internal cuneiform as just stated, or, being more externally placed, it may skirt the inner side of the base of the second metatarsal, close alongside its junction with the inner cuneiform, or, finally, it

may take a mid-course between the two, thus overlying both bones.

It can therefore, I think, be easily shown that this vessel always crosses the middle cuneiform bone, that it sometimes entirely avoids the internal cuneiform, and, moreover, that when it touches this latter bone it is for a distance short in comparison to the length of its path across the middle cuneiform bone.

The diagram, drawn from a recent dissection, will help to make these relations clear.



Line indicates the course of the artery over the tarsus.

RESEARCHES INTO THE HISTOLOGY OF THE CENTRAL
GREY SUBSTANCE OF THE SPINAL CORD AND
MEDULLA OBLONGATA. By W. AINSLIE HOLLIS,
M.D. Cantab., *Brighton*. Part II. (PLATE IV.)

IN a former paper (*Jour. of Anat.* xvii., 517, *et seq.*) I have traced the relationship which exists between the subepithelial tissue surrounding the spinal canal and the polio-synectic tissue of the central nervous system,¹ I shall now briefly mention a physical peculiarity of this tissue heretofore I believe overlooked. When a deeply-stained section of the cord is mounted in balsam solution, after immersion in oil of cloves, its surface appears to the naked eye to be nearly uniform in colour and texture. When, however, we allow transmitted light to pass through the object, we perceive the central grey nucleus and its appendages to be distinctly darker than the rest of the section. The deeper hue is due to the great transparency of that portion of the section, as may be readily shown by looking at distant objects through the specimen. It is doubtful what causes the great transparency of this portion of the cord. It may be that there exists a close similarity between the refractive indices of the synectic tissue and those of the menstrua used in mounting the specimen, and that the homogeneity or closeness of texture of the grey matter is greater than that of the surrounding white material. The peculiarity is observable in both longitudinal and transverse sections. Gerlach states that synectic tissue² (neuroglia) is not stained by carmine solutions. This statement must be modified. In well-stained specimens the synectic tissue is visibly tinted, although less deeply than the nuclei, ganglia-cells, and grey nerve fibres (axis cylinders). Gerlach³ unwittingly contradicts himself on this subject of tissue-staining. He had elsewhere stated that portions of the posterior columns of the cord are richer in this tissue, and hence stain a deeper red with carmine than the rest of the white

¹ I have elsewhere given the derivation of *polio-synectic*.

² Excluding the connective-tissue cells.

³ Cf. pp. 340 and 345, *Stricker's Hand-book of Comparative Histology*, N.S.S., vol. ii.

substance. If we attempt to differentiate the grey substance of the cord and medulla by the transmitted light test I have mentioned, we shall find in the cord the cornua and commissure are most translucent, whilst Goll's columns occupy an intermediate position between the grey and white substance, corresponding to the greater amount of synectic tissue observed therein by Gerlach. The grey substance of the medulla is mapped out with similar distinctness by this method. I shall, however, reserve a description of the latter organ for another occasion.

The Intermediate Lateral Tract.—A successful longitudinal section of this tract and the corresponding anterior cornu in the cervical region shows in a marked manner the difference which exists in the shape and the arrangement of the cells in these adjacent regions (fig. 1; cf. *Jour. of Anat., op. cit.*, p. 520). The tract consists of clusters of small (mostly pyriform) cells arranged linearly, and dissociated from each other and from the column of sparsely scattered giant cells, to which they are contiguous by a delicate fibrillar stroma of synectic tissue. In the mid-dorsal region of the cord I have observed two adjacent columns of these cell-clusters.

The Vesicular Columns of Clarke.—The cellular elements of these columns occupy, as regards their size, an intermediate position between the giant cells of the anterior horns and those of the tract I have just described. These columns, as I have before stated, offer many examples of the pyriform cell, and they extend occasionally (contrary to what is usually stated in text-books) as low as the commencement of the *filum terminale*. The cell clusters are larger and more numerous in the lower dorsal region than elsewhere. In the cervical region of the cord these vesicular columns disappear. Only an occasional cell imbedded in a nucleus of synectic tissue marks their upward extension towards the medulla. At the cephalic extremity of the cord a slight well-defined protuberance of synectic tissue at the base and inner side of the posterior cornu (fig. 2, "p'"), that is in the situation of the upward extension of Clarke's column, becomes again observable, and denotes the point of separation of the *caput (substantia gelatinosa Rolando)* from the rest of the grey substance of the posterior cornu in the medulla (fig. 3, "p'"). The columnar prolongation above described contains very few cellular elements

at the union of the medulla and cord, and it is not until it has passed upwards on a level with the decussation of the anterior pyramids that numerous cellular elements are again visible within it (fig. 4, "pp"). In a transverse section of the medulla made on a level with the lowest portion of the olivary body, this protuberance of grey substance which I have ventured to identify as an upward prolongation of Clarke's column, becomes much enlarged, expanding backwards and outwards, and forms the *nucleus cuneatus* of anatomists (fig. 5, "p"). The many cellular elements within this grey columnar extension¹ lend support to this view, as they closely resemble, both in their form and size, the pyriform cells observable in Clarke's vesicular columns of the dorsal cord.

Goll's Tract in the Medulla.—The posterior median columns of the cord (fig. 2, *gg*), when traced upwards from the cervical region, are found to shorten and widen as they enter the medulla. This widening is due to the interposition of numerous radiating strands of synectic tissue between the white fibres of the tracts. The radiating strands of grey tissue are not confined to Goll's columns, but are observable in a variable degree throughout the whole of the white substance between the tubercle of Rolando and the posterior fissure at this part of the medulla. One of these strands is very constant in its appearance on either side at the extremity of the cuneate nucleus, and is named sometimes the external cuneate nucleus (figs. 3 and 4, *p'*, *p'*). At the lower part of the medulla the grey strands of synectic tissue contain a considerable number of cellular elements, mostly pyriform in shape, and closely resembling those in the cuneate nucleus above described. At a level with the calamus the tracts I am describing expand laterally (fig. 6, *g*), becoming, at the same time, an elaborate network of synectic tissue surrounding white medullary fibres, and pushing outwards, as it were, the heads of the cuneate nuclei with their appendages (*p*, *p'*), the external nuclei.

¹ Especially on a level with the pyramidal decussation.

DESCRIPTION OF PLATE IV.

Fig. 1. Longitudinal section of the intermediate lateral tract and adjacent portion of the anterior cornu. Human adult. "aa," large multipolar cells of the anterior cornu; "bb," clusters of cells (mostly small pyriform) forming the lateral tract.

Fig. 2. Transverse section of the cord on a level with the third cervical vertebra. Youth aged 19 years. *Ant*, anterior cornu; *R*, substantia gelatinosa of Rolando; *c*, canal; "gg," Goll's columns; "p," prominence at base of posterior cornu.

Fig. 3. Transverse section of medulla at union with cord. The letters refer to similar parts in previous figure.

Fig. 4. Transverse section of medulla at the decussation of the pyramids. *p'*, external cuneate nucleus; *p*, cuneate nucleus.

Fig. 5. Transverse section of the medulla at the lowest portion of the olivary bodies. *ol*, accessory olivary nucleus.

Fig. 6. Transverse section of the medulla just below the calamus scriptorius. *ra*, raphé; *ol*, olivary nucleus.

ON SOME POINTS IN THE ANATOMY OF THE CHIMPANZEE (*Anthropopithecus troglodytes*). By J. B. SUTTON, Senior Demonstrator of Anatomy, Middlesex Hospital.

IN a paper communicated to the Zoological Society in 1835 "On the Osteology of the Chimpanzee and Orang Utan," Professor Owen writes as follows:—

"It has been no less a matter of surprise than of regret, that while the natural history of *Mammalia* which recede furthest from *Man*, and which inhabit the remotest regions, has been investigated with the most persevering and successful exertions, the species which are in immediate juxtaposition with him in his natural series should still remain almost as little understood as at the dawn of zoological science. We now, in fact, possess more accurate and detailed information respecting the economy and organisation of the paradoxical *Platypus* of Australia than we do with regard to the *Chimpanzee*, the most interesting of all the brute creation, from its close affinity to the human type of structure, which has long been known to inhabit the forests of Africa, and where there is every reason to believe that it is far from being rare."

At that time the censure was well deserved, but fortunately since that date anatomical literature has been enriched by careful and detailed descriptions of the dissections of numerous specimens of the Chimpanzee by the several anatomists into whose hands they have fallen.

The osteology of the creature has been principally discussed by Professor Owen in the paper already mentioned, and in his *Anatomy of Vertebrates*. Vrolik, of Amsterdam, published an excellent monograph in 1841, entitled "Recherches d'Anatomie Comparée sur le Chimpanzé." Dr Traill detailed certain facts concerning its myology as early as 1818, in the *Wernerian Transactions*. The *Boston Journal of Natural History* contains two papers on the muscles of the creature, one by Wyman, 1855, the other by Wilder, 1862. Duvernoy in the *Arch. des Muséum*,

tom. viii., 1855-6, "Des Caracteres Anatomiques des grands Singes pseudo-anthropomorphes," discusses at great length the anatomical characters of the Chimpanzee, Gorilla, Orang, and the Gibbons. Professor Humphry has described the *Arthrology* of this ape more in detail than any other writer in *Jour. of Anat.*, 1867, vol. i. Macalister noted certain points in the creature's myology in *Ann. and Mag. Nat. History*, 1871, and Professor Huxley has indicated the more important characters in his *Anatomy of Vertebrated Animals*, 1871.¹ During the past year I have had opportunities of dissecting two examples of the Chimpanzee, both young males, but one of them very much younger than the other, so that I was able to disarticulate the skull with the greatest ease.

In this paper I propose to treat of its osteology, myology, and such points in the nervous system and arteries as seem worthy of record.

With regard to the skeleton, most writers have instituted comparisons between the skull of the adult chimpanzee and the adult human skull, whereby the ape's cranium certainly suffers, and the human skull stands out in bolder relief. Let the comparison be made between the skull of a young Chimpanzee and a human foetus at birth, bone for bone, then many of the most marked peculiarities of the ape's skull, as contrasted with man's, vanish, and so far as the actual form and relations of the individual bones are concerned, the difference will be found not so great as might be imagined. It may be argued that it is unfair thus to contrast an immature skull with one that is thoroughly adult, nevertheless peculiarities of the foetal skull often persist even to adult life, and if a point of distinction in the adult also characterises the *foetal* skull, it at once raises it on sure ground as an *absolute* point of difference if it be wanting in the ape's skull. The bones composing the cranium will be first considered :—

The Sphenoid.—The pre-sphenoid is represented by a vertical plate of bone with two circular shallow depressions on each side. At its upper and anterior part it forms a distinctly triangular projection, which passes between the almost opposed orbital plates of

¹ Dr Champneys has described in this *Journal*, vi., p. 176, Nov. 1871, the muscles and nerves of the Chimpanzee, and compared them with those of Anubis.

the frontal bone to gain the cribriform plate of the ethmoid. Were it not for this narrow spine, the pre-sphenoid would be completely bridged over by the union of the two horizontal plates of the frontal posterior to the ethmoid bone. Two large sinuses occupy the base of the pterygoid process, the lingulae, and the adjacent parts of the ali-sphenoids. The vidian canal, which is very small, gives rise to a projection on the floor of each sinus, and near the anterior part lies exposed in the cavity. The ali-sphenoid is prevented from articulating with the parietal by reason of the squamosal passing between the two bones to join the frontal, as it does occasionally in man. At birth the ali-sphenoid is separated from the parietal by means of a fontanelle, and very frequently a large wormian bone known as the *epipteric* bone occupies this situation in the adult skull.

The sphenoidal fissure is large; in one of my specimens the foramen rotundum is not separated from the fissure. The foramen ovale is not complete in the sphenoid itself, but appears as a deep notch in the hinder border of the ala, requiring the junction of the pterotic portion (tegmen tympani) of the temporal bone to make it a complete foramen. The large size of the sphenoidal fissure and the condition of the foramen ovale correspond exactly with the appearance of the parts in the human foetus but a foramen rotundum communicating with the fissure, I have never seen in man. This condition of the foramina is interesting in connection with a rule which I have formulated with regard to the foramina of the human skull. *Whenever a nerve pierces a bone, it marks the confluence of two or more ossific centres, or the foramen transmitting a nerve is formed by the apposition of two or more bones.* Thus the optic foramen is formed by the orbito- and pre-sphenoids, the vidian canal by the junction of lingula, ali-sphenoid, and internal pterygoid process, the mode of formation of the sphenoidal fissure is obvious, and that of the foramen ovale has been described. The most apparent explanation of the foramen rotundum is to regard it as a segment of the sphenoidal fissure, unless the statement of Rambaud and Renault can be verified (*Origine et Developpement des os*, Paris 1864), that the inner portion of the ali-sphenoid and the external pterygoid process have a separate nucleus. Some indication of this is afforded by the fact that a

deep fissure extends from the posterior border of the ala almost to the foramen rotundum in foetal skulls. If this nucleus can be shown to exist, the only exception to this rule concerning nerve-foramina vanishes.

The Occipital Bone.—Obliquity and backward position of the foramen magnum, smaller proportionate size of the condyles, and occipital protuberances, with faintly marked curved lines, are attributes of the occipital bone of the foetus of man, and of the adult Chimpanzee. The anterior condyloid foramen at birth appears as a notch in the ex-occipital, but is converted into a foramen by the basi-occipital. Later, when these two parts are anchylosed, the hole appears entirely in the ex-occipitals, but the mode of its formation clearly shows that it forms no exception to the rule mentioned regarding nerve exits.

The ethmoid bone lacks a crista galli, or has it only faintly marked, and the occasional failure of the perpendicular portion of the bone to reach the nasal and frontal bone are the chief points of interest in this element of the skull.

The Frontal Bone.—The more important features of this element of the skull are the absence of the nasal spine and supra-orbital notches, the situation of these being marked merely by foramina leading from the diplöe. The horizontal or orbital plates come nearly into contact, so that the olfactory fossa, but for the intervention of the small spine of the pre-sphenoid, would be completely encircled by the frontal. The superciliary ridges are large and prominent. In one of my specimens the frontal sends down a process to join with the orbital plate of the superior maxilla. The process in question passes between the lachrymal and os planum of the ethmoid, completely separating these two bones. At birth the human skull lacks nasal spine and supraorbital notches.

The Temporal Bone.—This presents peculiarities, some of which are never found in the skull of man at any time of its development. The Chimpanzee and human foetus agree in the following points :—There is no ossified stylo-hyal, but an ossicle representing the tympano-hyal is discoverable in both; the mastoid process lacks the prominence so characteristic of it in adult human skulls, there is a well-marked petro-squamous suture, and a vaginal process is wanting. In the Chimpanzee the floccular fossa

is absent, the post-glenoid tubercle large, and the tympanic membrane is situated at the bottom of a long bony external auditory meatus; the zygoma is large. This latter group of characters is never found in the skull of the human foetus, so that the differential points of this bone are well marked and distinctive.

THE FACIAL BONES.

One of the most striking attributes of the facial skeleton of the human foetus is its small size compared with the brain case. This character is, of course, still further enhanced when compared with the facial skeleton of the Chimpanzee. Beyond the contrast of size, the two sets of bones have very much in common when they are examined one with another.

The Superior Maxilla.—One of its peculiarities is the persistence of the premaxillary bone to near the end of the first dentition and the extent to which it bounds the anterior nares, reaching up to the nasal bone, so as to completely exclude the superior maxilla from taking any part in forming the boundary of the anterior nares. I have in my collection numerous specimens of the superior maxilla taken from foetuses at birth, where a process of the premaxilla may be clearly seen extending upwards and touching the nasal bone, so that in some cases at least the anterior nares of man are bounded by the premaxilla on their lower and outer sides.

The infraorbital foramen in the Chimpanzee is frequently double, sometimes single on one side, double on the other, so that this is evidently a variable character. If these foramina be carefully examined, the bridge of bone separating them from the orbit will be found traversed by a suture. The human superior maxilla presents a similar fissure at birth, and in adult skulls of the lower races of mankind, marking the point of union of two of its centres, the seat of ankylosis between the nasal process and the outer part of the maxilla being accurately indicated by the passage of the infraorbital branch of the fifth cranial nerve. In some skulls of the Chimpanzee the supernumerary infra-orbital foramina occupy the suture between the maxillary and malar bones. The preponderance of the alveolar process in the

foetal jaw is another circumstance worthy of note in comparing the foetal skull with that of the ape's.

The Malar Bone.—In the Chimpanzee, as in the human foetus, the malar is a bone of relatively considerable size. In one of my specimens the bone is partially traversed by a suture, and in the fissure three nerve foramina exist. This is a point of some interest in connection with the rule regarding nerve foramina previously detailed. In the text-books of human osteology, one centre of ossification is given for the malar bone, but, in reality, ossific material is deposited in three distinct places during the development of the skeleton, and the nerves pierce the malar bone in a line exactly corresponding to the confluence of the three primary nuclei. Even in adult human skulls the malar has been found traversed by a suture.

The Palate Bone of the human foetus and Chimpanzee present harmonious features, in the fact that the vertical plate is of no greater extent than the horizontal portion, and the foramen in its vertical plate is not sphenopalatine but ethmo-palatine, for it is completed by the lateral mass of the ethmoid. The Chimpanzee's palate bone only just peeps into the orbit by a very narrow border, but its sphenoidal process articulates to a considerable extent with the vomer on the inner side of the nasal fossa; whereas in man the alæ of the vomer and the palate bones scarcely come into apposition.

The Vomer is more pointed anteriorly than in man, and crosses the incisive foramen, whereas in him it is kept back by a jutting process of bone which springs up from the premaxilla.

The Inferior Maxilla exhibits a condition never found in man; its large symphysis, single median genial tubercles, upper and lower, and the absence of a chin, are obvious points of difference.

The single *nasal* bone, so characteristic of this ape, and the want of convexity, are two very striking points to note; but examples of obliteration of the nasal suture occasionally occur in man, and of which there is one very good example in the Museum of the Middlesex Hospital.

The *lacrimal* bone has two grooves, one lodging the nasal duct, the other receiving a projection from the nasal process of the superior maxilla.

The *turbinals* possess little of interest. They occupy a large portion of the nasal fossæ, agreeing in this respect with the human foetus.

There yet remains some points to notice with regard to the skull.

In the Chimpanzee the length of the cranium in each of my specimens is exactly twice the length of the basi-cranial axis, against $2\frac{1}{4}$ times the excess of the cerebral length over the same axis in adult human skulls. Curiously, in the human foetal skull, the cerebral length, in several specimens promiscuously selected, exceeded the basi-cranial axis three times in all the instances chosen. This is due, I believe, to actual preponderance of brain and not to relative shortness of the base of the skull.

The cranio-facial angle of man is distinguished from that of all mammals by the fact that, though it may be as open as 120° , yet in the higher races it frequently approaches 90° . In the foetal skulls from which the measurements recorded above were taken, this angle invariably measured 120° , *i.e.*, the lowest limit. In one of my Chimpanzees the cranio-facial axis equals 115° .

The superciliary ridges of the Chimpanzee are very large, but the prominence of these ridges is equalled in the skulls of some of the natives of New South Wales.

The orbits, too, of the ape, in that they measure much more in the horizontal than in the vertical diameter, are by no means exceptional, this being a constant character in the foetus at birth, and found frequently in the skulls of the lower races of mankind.

The sutures of the human skull remain long persistent, and when obliteration commences the process usually occurs first at the spot (named the *obelion*), corresponding to the posterior fontanelle of the infant. In the Chimpanzee, on the contrary, the *temporo-parietal* and *temporo-occipital* sutures are the first to suffer obliteration, and it occurs at an early period in the life history of these creatures, sometimes even before the end of the first dentition.

Reviewing collectively the differences presented by the skull of the Chimpanzee when compared with the human cranium, it is very obvious they must be divided into two classes :—

I. Those which occur as anomalies in the skull of man, and

which for the most part consist of a persistence of conditions met with in the skull of the foetus at birth. To such I would give the name *relative differences*. This class should include the following:—

1. Absence of nasal spine.
2. The relative preponderance of the facial skeleton.
3. Absence of mastoid, styloid, and vaginal processes.
4. Articulation of squamosal with the frontal bone.
5. The large superciliary ridges and absence of the supra-orbital foramina.
6. The mode of formation of the foramen ovale.
7. The large alveolar processes of the superior maxillæ.
8. Small size of occipital condyles.
9. The fusion of the nasal bones.
10. The width of the orbits exceed considerably their vertical height.
11. The relation of the pre-maxillæ to the anterior nares.

II. Those conditions peculiar to the skull of the Chimpanzee, and which have not been described as occurring in the skull of man from birth upwards, I would term *absolute differences*. This list would include:—

1. The cerebral cavity less than $2\frac{1}{4}$ times the length of the basi-cranial axis.
2. The cranio-facial angle more than 120° .
3. The early obliteration of the temporo-parietal and temporo-occipital sutures.
4. The long bony external auditory meatus.
5. Diastema between the canine and adjoining teeth.
6. The anterior divergence of the superior alveolar arches.
7. Obliquity of the glenoid fossa and the large size of the glenoid tubercle.
8. The absence of a chin.
9. The large size of the foramina of exit of the cranial nerves.

It must be borne in mind that simian characters occasionally found in man's skull are *constant conditions* in the skull of the Chimpanzee, a fact of no mean importance in drawing a boundary line between the two groups *Anthropomorpha* and *Anthropidæ*.

THE HAND.

Compared with man, the most noteworthy points in the hand of the Chimpanzee are the diminutive size of the thumb, its apex not reaching beyond the metacarpo-phalangeal articulation, the small size of the trapezium and trapezoid, the large size of the pisiform bone, and the length and slender form of the metacarpals. That these characters may now and then be found in the hand of man there can be no doubt, for in the Museum of the Middlesex Hospital there is the skeleton of a hand with diminutive trapezium and trapezoid, and a thumb whose distal end reaches no lower than it does in the manus of the ape. Diminutive size of the pollex is not an absolute feature of this ape's skeleton.

There remains yet one point in connection with the skeleton that requires notice, for it seems to have escaped attention. If the tibia of the Chimpanzee be compared with the corresponding bone of the human skeleton, it will be observed that in man the articular surfaces of the tuberosities look directly upwards, whereas in the ape, on account of the forward curve which exists in the upper part of the tibia, the surfaces for the femoral condyles look backwards and somewhat upwards. A condition precisely like this exists in the tibia of the human foetus at birth.

THE MUSCULAR SYSTEM.

It is customary in describing the muscles of the Chimpanzee, to mention only those which differ from the descriptions given by previous anatomists; this necessitates much tedious reference; to avoid this I have given an account of those muscles only which vary in their attachments, taking the condition of the muscles usually found in man as the standard. Wherever a muscle is omitted it signifies that its attachments accord with those of man.

The Muscles of the Face.

The muscles of the face were little differentiated and pale in colour; the muscles of the auricular region were absent.

The *Occipito-frontalis* was represented by muscular fasciculi, very pale and delicate, but nevertheless well pronounced.

The *Orbicularis palpebrarum* was fairly well developed, that portion of the muscle near the median line meeting with its fellow of the opposite side across the azygos nasal bone; some of these fibres were attached to the nasal bone, thus representing the pyramidalis nasi muscle.

The *Corrugator supercilii* was detected as a small slip lying under cover of the orbicularis palpebrarum.

The *Orbicularis oris* was seen as a broad elliptical sphincter, encircling the mouth, receiving a broad sheet of muscle fibre in its upper moiety in which thickenings alone represent zygomatic, levator anguli, and levator labii superioris muscles. A similar muscular stratum, prolonged from the platysma myoides, alone represent the muscles which in man act on the lower lip. The lips were large, loose, and capable of extensive protrusion.

The Muscles of the Neck.

The *Platysma myoides* was present as a broad muscular expansion, stretching over the triangles of the neck; passing over the lower jaw it ended by becoming continuous with the facial muscles. The muscle was far thicker than in man.

The *Sterno-cleido-mastoid*.—This consisted of two parts, one arising from the manubrium sterni, and being inserted into the mastoid portion of the temporal bone and into the squamous portion of the occipital bone, along the superior curved line; the clavicular portion remaining distinct, was attached to the lateral mass of the atlas; the spinal accessory nerve passed between the two portions.

The muscle called *Levator claviculæ*, and described by several anatomists, was not present. The depressors and elevators of the hyoid bone call for no special comment, except that the sterno-hyoid muscles were separated more than is usual in man by the laryngeal sac.

The Muscles of the Back.

The trapezius presented the usual conditions found in man but was somewhat blended with the latiss. dorsi below.

The *Latissimus dorsi* sent the slip down to the internal condyle known as the *dorsi-epitrochlearis*, but the additional slip so frequently found crossing the axilla in man, and certain of the quadrumana, was not present.

The *Rhomboids*, minor and major, were represented by a single muscular sheet.

The *Levator angula scapulæ* arose from the tubercles of the transverse processes of the five upper cervical vertebræ, the slips of origin remaining distinct until near their insertion into the superior angle of the scapula.

The *Serratus posticus inferior* was inserted as in man into the outer surface of the ninth, tenth, eleventh, and twelfth ribs, just external to their angles.

Nothing of interest was noted in connection with the remaining lumbar muscles.

The Muscles of the Upper Limb.

Pectoralis major.—The muscle lacked the division into external and clavicular portions so constant in man. The groove usually found between it and the deltoid muscle was absent, many fibres of the pectoralis major becoming continuous with those of the deltoid.

Pectoralis minor.—A small muscle arising from the third, fourth, and fifth ribs external to their junction with the cartilages, then forming a narrow rounded tendon four inches in length to pass over the coracoid process of the scapula to blend with the upper part of the capsule of the shoulder joint.

Deltoid.—Fairly well developed, some portions of its inner border blended with the pectoralis major. Between the deltoid and the capsule of the shoulder-joint there was an enormous bursa extending under the acromion and coracoid processes.

Biceps.—Possessed two heads of origin which united very low in the arm.

Coraco-brachialis.—This muscle was inserted into the upper third of the inner border of the shaft of the humerus, and into the capsular ligament. The fibrous arch so frequently found stretching across the tendon of the teres major, and receiving

part of coraco-brachialis in man, was not represented. The external cutaneous nerve was absent, consequently the muscle was not divided into two parts, as is usual in man, to allow of the passage of the nerve. This condition of things is far from uncommon in the human subject. I met with it five times in thirty bodies in the winter session 1882. The rotator humeri of Wood was not represented.

The chief peculiarities in the muscles of the fore-arm result from the small size of the flexor longus pollicis, which leaves the middle portion of the shaft of the radius to be taken up by other muscles.

Flexor sublimis digitorum.—This muscle arose from the internal condyle of the humerus, the side of the coronoid process, and the oblique ridge of the radius; it then divided into *three* tendons, passing under the anterior annular ligament to be inserted in the bases of the second phalanges of the third, fourth, and fifth digits, after being perforated as usual by the deep flexor. The outer tendon came off from a muscular slip forming quite a distinct *flexor sublimis indicis* and had a tendinous intersection at its upper third. Its tendon was inserted into the base of the second phalanx of the index finger, after being perforated by the tendon of a deep flexor, which formed a *flexor profundus indicis*. This muscle, so far as its origin is concerned, corresponds exactly to a flexor longus pollicis, for it arose from the middle portion of the shaft of the radius, on the anterior surface, between the supinator brevis and the pronator quadratus; it had, in addition, an accessory slip springing from the side of the coronoid process of the ulna as is usual with the flexor longus pollicis, the tendon then passed to be inserted into the terminal phalanx of the index finger after perforating the superficial flexor; as the muscular belly approached the angular ligament, a small bundle of pale fibres, gradually terminating in a very thin but distinct tendon, were inserted into the terminal phalanx of the pollex as the representative of the *flexor longus pollicis*.

Flexor profundus digitorum arose as usual from the ulna, but consisted of three tendons, the first, or one going to the index digit, being separate as described above; the three inner tendons going to the three inner digits piercing the sublimis as is usual.

The flexor tendons were provided with vincula and other accessories usually encountered in the flexor tendons of the human manus.

The *Extensor ossis metacarpi pollicis* had a divided tendon, the outer slip being inserted into the os trapezium, the other to the outer side of the base of the metacarpal bone of the pollex:

Extensor secundii internodii pollicis was inserted into the bases of the first and second phalanges of the pollex.

Extensor primi absent, but *extensor indicis* well formed.

Abductor, opponens, flexor brevis, and *adductor pollicis* were present; the adductor, in addition to its usual insertion into the base of the first phalanx, sent a small tendon to be attached to the base of the second phalanx.

The Muscles of the Lower Limb.

The *iliacus* has the same relations as in man, but is not so large relatively as in him.

The muscle which calls for comment more than any other in the thigh is the one named *Scansorius*. I believe it was first described by Traill (1818). He writes concerning it:—"The most remarkable muscle about the top of the thigh has not been noticed by Tyson, Camper, Cuvier, or the older anatomists. It is a flat triangular muscle arising from the whole anterior edge of the ilium to within half an inch of the acetabulum, and is inserted to just below the fore part of the great trochanter, between the head of the cruralis and the vastus externus, a little below the origin of the former; it is thin and fleshy throughout its whole extent, except where it is inserted by a very short, flattened tendon. At its upper part it is united by cellular substance to the iliacus internus. The action of the muscle which appears to be peculiar to this animal is to draw the thigh upwards towards the body; and it seems especially intended to assist in climbing. On this account we propose to call it the *scandens* or *musculus scansorius*, and we are disposed to regard this as one of the principal peculiarities of the muscle." The description of the muscle, as given by Traill, accord with those in my specimens in every particular. This muscle will be referred to later on.

Sartorius, rectus, and quadriceps extensor have similar relations to those usual in man, but the rectus had only the straight head.

The *Gracilis* was very broad, as in *quadrumanus* generally.

The *Adductor magnus* is fleshy, even to its insertion into the tubercle on the internal condyle.

Biceps femoris possessed only an ischial head; semi-membranosus and semi-tendinosus had nothing beyond their usual attachments.

The *Tibialis anticus*.—This muscle was of good size, arose from the tibia as in man, as the tendon neared the anterior annular ligament it divided into two, one strong slip being inserted into the inner surface of the internal cuneiform; the other, the smaller of the two, passed to its insertion into the inner surface of the base of the metatarsal bone of the hallux. This resembles in a very forcible way the *ex. ossis. metacarpi pollicis*.

Peroneus tertius not represented.

The *Gastrocnemius* was fleshy even to its insertion into the os calcis.

The *Soleus* arose from the upper third of the posterior surface of the fibula only, was fleshy even to its insertion into the os calcis, and remained distinct from the gastrocnemius muscle throughout.

The *Plantaris* was present with its usual peculiarity of tendon, and was attached on the inner side of the calcaneum.

Popliteus was present.

The *Flexor longus hallucis* arose from the posterior surface of the fibula, passed in a groove formed by lower end of tibia, astragalus, and os calcis; its thick and strong tendon then split, one piece being inserted into the terminal phalanx of the hallux, the remaining two tendons being inserted into the last phalanges of the third and fourth toes, after piercing the corresponding tendons of the flexor brevis digitorum. This occurs as an anomaly in man, and was the condition of this muscle in the foot of the Bushwoman dissected by Professor Flower and Dr Murie (*Jour. of Anat.*, vol. i., 1867).

The *Flexor longus digitorum* arose from the posterior surface of the shaft of the tibia and from its inner tuberosity; it passed under the internal annular ligament, and in the sole of the foot divided—one tendon was inserted into the terminal phalanx of the

second, the other into the corresponding part of the fifth toe, perforating on their way the flexor brevis tendons. The tendon of the long flexor blends with the short flexor in the sole of the foot.

The muscles of the first layer in the sole of the foot were four in number, as is so very frequently the case in man, viz. :— abductor hallucis; abductor minimi digiti; the *abductor ossis metacarpi quinti digiti*, which arose from the outer side of the os calcis, and was inserted into the base of the fifth metacarpal bone; and the flexor brevis digitorum or perforans, which arose from the os calcis by a tendon common to it and the abductor pollicis. Some of its fibres join the long flexor in the middle of the foot; it then ends in three tendons, for the second, third and fourth toes, which, after splitting to allow the long flexor to pass through, unite again for insertion into the base of the phalanges.

Accessorius not represented.

Lumbricales, four in number, and of good size, arose in the following order :—

The inner one came off from the tendon of the long flexor; the second, third, and fourth arose from the tendons given off by the flexor hallucis, the outer tendon affording origin to the third and fourth lumbricales. They all passed to the tibial side of the four outer toes to join the expansion of the extensor tendons.

Flexor brevis hallucis well formed. The *adductor* arose from the sheath of the peroneus longus, the heads of the four outer metatarsal bones, and from a considerable portion of their respective shafts, so that it appeared as a broad triangular muscle hiding the metatarsal bones from view, with its apex attached to the outer side of the base of the first phalanx of the hallux in common with the outer portion of the flexor brevis hallucis.

The *interossei* were arranged as in the hand, the middle toe affording attachment to the second and third of the dorsal series, so that the imaginary line of action of these muscles passed through the third toe, and not the second as is usual in man.

On comparing the muscular system of the Chimpanzee, it will be found to differ from that of man in few important particulars. Those most deserving attention are the modification of the muscles of the *pollex*, the *scansorius*, the *dorsal interossei* of the foot, and the absence of *peroneus tertius*.

All published accounts of the dissection of the creature show that the *flexor longus pollicis* is either extremely small or absent. This alteration in the size of the muscle renders vacant a considerable space on the anterior surface of the shaft of the radius; this area of bone usually becomes taken up by the outer portion of the *flexor profundus digitorum*, which in some cases differentiates into a distinct muscle, *flexor profundus indicis*. The interest of this condition centres itself in the explanation it offers as to the mode of differentiation of distinct muscles from a common muscular sheet: a tendon rises from a certain number of muscle-fasciculi; the digit receiving that tendon is used more frequently than its fellows, hence that portion is called upon to contract with greater frequency, and, as a consequence, that part of the common mass belonging to the tendon in question becomes specialised as a separate muscle.

The existence of an *extensor primi internodii pollicis* has not yet been recorded. Wilder professes to have seen one, but his account of the dissection clearly shows that the tendon he describes was really part of the *extensor ossis metacarpi*, for he says it was inserted into the radial side of the base of the metacarpal bone of the thumb.

The *scansorius* requires some further notice. It would appear that this muscle really represents the *tensor vaginæ femoris* of anthropotomy, except that it is inserted into the femur instead of the fascia of the thigh, but this difference may be readily explained by the peculiar conformation of the hip-joint in this ape. On looking at the living Chimpanzee, one cannot fail to notice the facility the creature possesses of raising the lower limbs at right angles to the trunk in the abducted position, so that when both legs are thus stretched out the heels and ischial tuberosities are in one straight line. This position is admirably shown in the figure of an Orang in Cuvier's *Règne Animal*. To put the legs in this position in the human subject would cause dislocation of the hip-joint; yet the apes assume this position with the greatest ease, chiefly on account of the shallowness of the acetabulum and the more flattened shape of the head of the femur. The *scansorius*, on account of its insertion just below the greater trochanter, must be a powerful agent in raising the femur to this horizontal position. If we compare the construc-

tion of the hip-joint of the Chimpanzee with that of man, we shall find that in man the acetabulum is deeper, and the head of the femur more globular, so that the movement of abduction is restricted; consequently the utility of the muscle is limited to that of an abductor and rotator, its development becomes of secondary importance; hence its attachment to bone gradually falls away, and it remains as the *tensor vaginæ femoris*, with fascial attachment only. In Professor Humphry's dissection the scansorius was absent, but the tensor vaginæ was represented.

The absence of the *peroneus tertius* seems to be a prevailing condition in the Chimpanzee.

The *dorsal interossei* of the foot taking the *middle toe* and not the second as their central line of action, is another constant condition in the Chimpanzee.

With regard to the muscular system, it would appear that the following list includes the principal peculiarities of the muscles which may be ranked, under our present knowledge, as *absolutely* differing from man:—

1. The scansorius (*tensor vaginæ femoris*), its insertion into the femur.
2. Absence of, or puny size of, flexor longus pollicis.
3. Absence of extensor primi internodii pollicis.
4. Absence of *peroneus tertius*.
5. Gastrocnemius and soleus inserted separately, the muscles continuing carneous to their insertion, and the soleus possessing only a fibular head.
6. The large size of the adductor hallucis.
7. The third toe having two dorsal interossei attached to it instead of the second toe, as in man.

THE ARTERIES.

Few peculiarities of the blood-vessels occurred worthy of note. The arch of the aorta gave off its three large trunks, as is the usual arrangement in man, but it possessed in addition a rather large thyroidea ima: it arose from the aortic arch between the origin of the innominate and the left carotid arteries, passed vertically upwards on the trachea to within half an inch

of the cricoid cartilage, to be distributed to the mass of tissue representing the remains of thymus gland. This is of some interest, for I feel certain that the occasional existence of this little artery may be explained in the following manner:—The thymus gland derives its blood supply from the aorta, innominate, and occasionally the right carotid or internal mammary arteries; gradually the gland atrophies, usually the nutrient vessels dwindle and generally disappear, or remain as the tiniest twigs to the neighbouring cellular tissue, but now and then one or other of them persists, increases in calibre, and becomes of a size sufficient in importance to demand a name—*thyroidea ima*. This account of its growth will also explain its variable place of origin—sometimes the aortic arch, at others the innominate, carotid, or internal mammary arteries.

The *arterial polygon* at the base of the brain was formed as in man, except that the anterior cerebral arteries, instead of being connected by an anterior communicating, joined and formed a single trunk for an inch of the course, then bifurcating, were distributed as usual. This is interesting, not only as an occasional condition found in man, but also an example that *arteries running in the same direction and parallel have a tendency to fuse together*.

The *anastomotica* of the femoral possessed a very large superficial branch, which accompanied the internal saphenous nerve down the leg, finally to pierce the first interosseous space to join the deep plantar arch. The anterior tibial artery existed, but was very small. This condition of the superficial branch of the *anastomotica* is frequent in many animals I have dissected; now and then a large artery may be found accompanying the saphenous nerve in man, and has been named the *great saphenous artery*.

THE NERVES.

It has long been contended by physiologists that the motor branches of the vagus which enervate the muscles of the larynx are in reality derived from the spinal accessory, and certain authors have stated in support of this view that, in the Chimpanzee, the spinal accessory sends a branch direct to the larynx, and this twig has no connection with the vagus. The author of

the statement that the spinal accessory does send such a branch is Vrolik, who, in the monograph referred to at the commencement of this paper, not only describes but actually figures the nerve in question. Such a condition as this, if it really existed, would of course have a very important bearing on the question as to the source of the motor nerves of the larynx; but unfortunately Vrolik's statement cannot be verified. The relations of the ninth, tenth, and eleventh cranial nerves correspond to those of man in both my specimens. Vrolik also states that the condition of his Chimpanzee was such as not to admit of the careful dissection of the brain and cranial nerves, on account of its being badly preserved. Vrolik and Champneys appear to be the only anatomists who have published an account of the nerves of this creature; possibly others have found so close a resemblance to man in this respect as not to deem it necessary.

In both my specimens I found that the *glosso-pharyngeal* nerve sent off a branch which pierced the sheath of the hypoglossal nerve immediately after it hooked round the occipital artery, then, quitting the nerve, joined the descendens noni so as to form part of the *ansa hypoglossi*.

The *musculo-cutaneous* nerve of the brachial plexus did not exist as a separate branch, but the muscles usually supplied by it received their nerves from the median. I met with this anomaly five times in twenty-two subjects in the winter session 1881-82.

The *second dorsal nerve* did not send any branch to assist in the formation of the brachial plexus, as it frequently does in the Macaque monkey and in man. This condition has lately assumed some importance in relation with Ferrier's researches on the nerves of the iris.

The *median* is curiously arranged in this animal. After passing the elbow and distributing motor twigs to the muscles of the inner condyle, it gives off a rather large branch, which passes deeply beneath the muscles, and joins the ulna nerve just above the middle of the fore-arm; the main trunk continues down to the hand, and is distributed as usual to the muscles of the thumb, situated to the outer side of the flexor longus pollicis tendon, the two outer lumbricles, and the first three and a half digits, exactly as in man. It is the communication with the

ulna that is worthy of attention, for it was constant in both fore-arms of my two specimens. Vrolik records it as present in one arm but not in the other, therefore he regarded it as an abnormality. I found it present in two Chimpanzees, Macaque, Ateles, and Cynocephalus. After the branch joins the ulnar nerve, if a little care be exercised, it may be easily traced to the palm, where it supplies one and a half fingers, and takes on, in fact, the distribution of the ulnar nerve; but the true ulnar nerve, after giving off a very small twig to the median portion, turns to the back of the hand to supply one and a half fingers. By this arrangement the median nerve supplies the whole of the palm of the hand. In man I have five times found a slip passing from the median nerve to the ulnar, lying deeply below the superficial flexors. I believe it was first described by Krause and Telgmann in *Les Anomalies dans le parcours des nerfs chez l'homme*, 1869, but is not very generally recognised as a frequent variation by anatomists.

OBSERVATIONS UPON THE OSTEOLOGY OF *PODASOCYS MONTANUS*. By R. W. SHUFELDT, M.D., *Captain Medical Corps U.S. Army; Cor. Memb. Società Italiana di Antropologia, Etnologia e Psicologia Comparata, Florence, Italy; Memb. Philosophical, Biological, and Anthropological Societies of Washington; Hon. Curator Sect. Avian Osteology, Smithsonian Inst.; Memb New Orleans Medical and Surgical Society, &c.* (PLATE V.)

WE find fifteen pluvialine birds enumerated in the latest authorised list¹ of our North American avifauna; these include the Continental lapwing (*Vanellus cristatus*), taken in Greenland, and another remarkable plover-like bird, the *Aphriza virgata*, or surf-bird, a form related to the sandpipers on the one hand, and connecting the *Hæmatapodidæ* with the *Charadriidæ* on the other. As thus constituted, these fifteen forms of American plovers are placed in six genera: *Squatarola* claiming one species, *Charadrius* three, *Ægialites* eight, *Podasocys*, our present subject, one, and finally, the genera just mentioned, *Vanella* and *Aphriza*, each one. All of these birds in the United States have a wide range of migration, appearing with remarkable regularity in some localities at certain times, both in spring and autumn, the majority of the species breeding far to the northward. *Podasocys* is confined largely to the west and great western plains. The skeletons in my possession of this bird were prepared by me from specimens collected on the arid plains of the territory of Wyoming during the summer of 1879. In 1859 but two of these birds were reckoned among the vast collections of skins in the Smithsonian Institution at Washington, and it still remains among the desiderata of collectors. Upon its native plains, and in the open parks of the great Rocky Mountains, it has all the habits and action of a true plover, lacking only in the noisy traits of *Vanellus* and *Ægialites*.

The plovers all belong to the family termed by Professor

¹ *The Coues Check List of North American Birds*, by Dr Elliott Coues, Boston, Mass., 1882.

Huxley the *Charadriomorphæ*, one of the families making up the great sub-order of the *Schizognathæ*, birds with well-defined characteristics of the osseous palate. These characters are too well known at the present writing to render it necessary for me to enumerate them here in detail; but, for the reader's convenience, the leading points will be briefly presented, by which means the memory may be refreshed before entering upon our subject, describing as we will the skeleton of a bird that claims his place in the ranks of this group. The characters of the *Schizognathæ* are:—

1. The maxillo-palatines are free within, and always exist as thin concavo-convex plates of bone.
2. The sternum is provided with a deep keel, and usually 4-notched behind.
3. The vomer is commonly narrow and forked behind, terminating in a free pointed extremity anteriorly.
4. The pterygoids and palatines articulate with the basi-sphenoidal rostrum.

In addition to these general characters, the *Charadriomorphæ* have the following special ones:—

1. Well developed basi-ptyergoid processes.
2. A long and slender rostrum.
3. The hallux occasionally absent, and when present always small.
4. "The phalanges of the anterior toes diminish in length from the basal to the penultimate" (Huxley).

When Professor Huxley gave to the world his admirable essay¹ upon the structure and arrangement of the palatal bones in birds, and of their value in taxonomy, he chose the common plover, from all the material at his hand, to illustrate the arrangement assumed by the *Charadriomorphæ*, so that in describing the cranium in *Podasocys* I will take special pains to compare these parts with like parts in the paper referred to, where *C. pluvialis* is treated.

It is through such comparisons and detailed descriptions of species from all parts of the world and every manner of

¹ "On the Classification of Birds, and of the Taxonomic Value of the Modifications of certain of the Cranial Bones observable in that class," *Proceedings of the Zoological Society*, April 11, 1867, pp. 415-472.

environment, with the type species of such a classification, that its tenets become tested and settled upon a certain foundation, or else are so influenced as to require perhaps alteration or remodelling. It is by such accumulative evidence, too, as essays devoted to exact description of skeletal characters of several forms of each family, or of only one form, as for that matter, that such a classification becomes finally perfected, and the universally accepted one. Even Professor Huxley himself, after a careful review and study of his Gallinaceous group of birds (*Alecloromorphæ*), was obliged to modify his first views to some extent, as they were published in the paper we had referred to above. The scheme of the classification of birds upon the form or arrangement that the naso-palatine structures assume, is a good one, and far in advance of anything heretofore attempted, being a step decidedly in the right direction, insomuch as it takes internal structures into consideration.

The writer sees no reason to alter his views, as elsewhere expressed,¹ upon the question of taxonomy, believing, as he does, that Professor Huxley's scheme presents eminently the best frame for a classification, to which all our subsequent discoveries in internal and external structure may be attached, but that the feather tracts of Nitzsch,² the ambiens muscle, and other points made by the lamented A. H. Garrod,³ together with all the time-honoured external characters, will eventually come into play.

Of the Skull.—There has always been something strikingly columbine to me in the outward appearance of a plover's head—a similitude that is by no means shaken when we come to examine the prepared skull, in which so many of the bones are arranged as they are in the cranium of a pigeon. The skull of *Podasocys* is extremely light and fragile, due to the access of air to numerous cells in certain parts of its interior, and likewise to a generous supply of diploë in other localities. I find in the

¹ "Contributions to the Anatomy of Birds," *Twelfth Annual Report of the late U.S. Geol. and Geog. Surv. of The Territories*, Washington, Government Printing Office, Oct. 14, 1882, p. 727.

² *Pterylography*, trans. from the German, by P. L. Sclater, Lond. 1867, p. 50.

³ "On certain Muscles of the Thigh in Birds, and on their Value in Classification," Part I., *Proc. Zool. Soc.*, 1873, pp. 626-644; Part II., *Proc. Zool. Soc.*, 1874, pp. 111-123, pl. xvii.

chick of the plover only a few days old, that the premaxillæ have thoroughly coalesced along the culmen of the beak, for its outer or anterior third, but the suture dividing them posteriorly along the nasal process of these bones is, at this tender age, distinctly visible, whereas all the sutures in the face become obliterated in the adult.

Posteriorly along its dentary border the premaxillary throws backwards two processes, each of which articulates by squamous suture, the first, the longer, the maxillary, with the maxillary bone; the second or shorter, called the palatine process of the premaxilla, with the palatine, on either side in the roof of the mouth of this bird.

Several foramina are seen on the sides of the culmen beyond the anterior border of the nostril.

One will see in Professor Huxley's figure,¹ *Charadrius plumialis*, on the under side of the premaxilla, just above the anterior curve of the nostril, a little process of bone pointing forwards. This is also seen in fig. 1 of my drawing in the Plate. In an adult plover it might puzzle one not a little to decide where this bone is developed from—it has all the appearance of being a long prolongation of the frontals, as in the old bird the nasals look like bony bars bounding the nostrils behind (fig. 1, *n.*). Turning to the chick, however, we find the nasals to be far more extensive bones than these bars we have referred to lead us to believe. They have each a broad expansion in front of the frontals, where they articulate with each other along the median line as far forwards as the nasal process of the premaxilla; here they contract and dip under this bone on either side, conforming themselves to its width and form, to still articulate with each other beneath it, as far forwards as the prolongation we called attention to in the figures, where they slightly diverge from each other, to terminate in pointed extremities.

Posteriorly the nasals throw down, obliquely forwards, straight bars of bone that bound the osseous nostrils behind, to be carried forwards over the maxillæ, on either side, to the maxillary process of the premaxilla, where they articulate by squamous sutures beneath that bone.

¹ When I refer to this figure it is the one given by Professor Huxley in his "Classification of Birds," &c., *Proc. Zool. Soc.*, April, 1867, p. 427.

This arrangement of the nasals is very much as we find it in the common pigeon.¹ As in the pigeon, too, the aperture forming the bony nostril is a long and very open one. It will be seen, after an examination of the figures, that the ethmoid extends well forwards in the plovers, thus affording above a spreading table for the frontals, nasals, and premaxilla to rest upon.

The *lacrymals* of our subject are not very large bones, and in the adult they anchylose with the anterior margins of the frontals, where they form the rounded anterior terminating margins of the orbital peripheries. In *Podasocys*, a lacrymal throws down an attenuated process that coalesces with the outer margin of the ante-orbital plate, or lateral mass of the mesethmoid. From this margin the lacrymal develops two spine-like processes that project forwards, the upper one being the longer, the lower one almost touching the maxillo-jugal bar; this one is wanting in *C. pluvialis* (Huxley), where the lacrymal does not descend so far as in *Podasocys*.

The ante-orbital plate long remains cartilaginous in the plovers, but eventually becomes a large, quadrate, osseous partition, effectually separating the orbit from the rhinal chamber. In *Podasocys* it is only pierced for the nasal nerve and vessels. It is the ossified pre-frontal process of the ethmoidal cartilage, and is not nearly so well developed in *Charadrius* as in our subject.

The vomer of the mountain plover is an extremely delicate and elongated bone; in front it runs out into a free and needle-like point, while posteriorly it is split for about half its length, and in the fissure thus formed rides the rostrum of the sphenoid. The vomer is held in its position on the rostrum by a sharp anteriorly projecting process from the palatine on either side.

Turning our attention to the palatine bone, we find that on either aspect of the osseous roof of the mouth it sends forward a "maxillary process," that commences behind at a point opposite where the inner plate of the body of the bone terminates, while anteriorly it anchyloses with the maxillary and premaxillary at their juncture. The maxillary process being a

¹ *Handbook of Vert. Dissec.*, by H. Newell Martin, D.Sc., &c., and William A. Moale, M.D., pt. 11, 1883, fig. 1. Macmillan & Co.

flattened narrow plate, lying in the horizontal plane, and placed below these bones. The body of the palatine is the expanded posterior portion, and it is separated from the fellow of the opposite side by quite a longitudinal space in front, where the inner margin of the body dips down to form the "internal lamina" of the palatine bone. Outwardly the body is produced still further down to form the "external lamina;" this part is drawn out behind to form the pterygoid process, and in this locality the two palatines touch each other on the under surface of the sphenoidal rostrum; from this point they lie along this bone, more or less near each other, as the superior margins of the palatines, which are produced forwards, as "ascending processes" that grasp the forks of the vomer in a manner already alluded to. This arrangement of the palatines is substantially the same as Professor Huxley has given it for *Charadrius*. Just such a longitudinal space, as separates the inner lamina of the palatines is found to exist between the maxillo-palatines for their entire inner aspects. Behind they project backwards as free rounded laminæ, the rounding being at the expense of the inner angles. The upper surfaces of the maxillo-palatines are convex, the reverse being the case beneath; several foramina of no small size pierce these delicate plates along their entire length. Anteriorly each bone has two processes, one, the stouter, connecting it with the palatines, the other, much more slender, with the maxillary, while between the two a circular foramen is thus produced.

An examination of a chick of a plover shows that the elements constituting the infra-orbital bar early unite, and the sutures are entirely obliterated in this slender style in the adult *Podasocys*. The maxillary, as its anterior element joins the bones, we described above, when speaking of the maxillo-palatines, in the manner mentioned. This union takes place at the foot of that bar thrown down by the nasal to form the posterior boundary of the nostril (fig. 1, *n*).

It will now be seen that the arrangement of the bony palate in *Podasocys* agrees very well with that of *C. pluvialis*.

The superior periphery of the orbit, formed by the frontal of the corresponding side, is raised upwards in such a manner as to be above the longitudinally furrowed interspace between these

cavities. This is well shown in the Plate (fig. 4). Several foramina pierce these tilted crests well within the margin, and principally posteriorly. Externally the vault of the brain-case, formed by the usual bones, is very thin and smooth, being sufficiently transparent on top in our subject to allow a tolerably fair view of the interior.

The rostrum of the sphenoid and the ethmoid have thoroughly amalgamated, and as both of these bones are very extensively permeated with air-cells, such intercommunication is found to exist between them, the former opens by a large aperture externally, just below the ear proper. All of the usual foramina on the anterior wall of the brain-case are very large, though thoroughly individualised, and this shrinkage of the osseous septa of the orbital walls is likewise extended to the bony partition between these cavities, where the separation between the ethmoid in front and the presphenoid behind has caused two large windows to exist in this plate. They are, in *Podasocys*, separated simply by a narrow band of bone (fig. 1, *t*) that runs between them roughly parallel to the rostrum; in *Charadrius* this does not meet the anterior wall of the brain-case opposite (Huxley).

Arising just above the foramen magnum, in all the true plovers that I have examined, as in the present subject, we observe a supra-occipital prominence, pierced on either side of its median bridge of bone by an elliptical foramen with its long axis placed vertically. The usual foramina for the transmittal of vessels and nerves at the base of the cranium are located in my drawing of these parts in the plate (fig. 3). They are all very minute in the mountain plover.

In examination of the base of the skull, in a chick only a few days old, of the Kildeer plover (*Ægialites vociferus*) I observe that the bony bridge that lies between the "supra-occipital foramina" is formed by the supra-occipital itself; it is cleft above at this stage, and stouter lateral masses are seen on either side of it. The basi-temporal is still distinct as an element, as are the ex- and basi- occipitals. More laterally we find that the squamosal sends upwards an ascending process, long and slender, that overlaps the posterior third of the rounded margin of the frontal, and itself makes the periphery of the orbit. This bone,

below, develops a "zygomatic process," marked by a semi-circular nick at its extremity, which arches over the articulation for the quadrate. In adults a sphenotic process is fully developed. The condyle is small and circular, with the notochordal notch nearly obliterated.

With respect to the *quadrate*, it is peculiar only in having its processes and shaft much compressed and plate-like—the orbital spur, making up nearly half the bone, is a triangular lamina, with its base applied to the entire length of the body of the shaft of the quadrate proper. A long narrow condyle surmounts the otic process, placed at right angles to this orbital offshoot, and the pit for the quadrato-jugal occupies the summit of a special process thrown out on the part of the mandibular portion. Rather undue shortening takes place in the shaft of a pterygoid, owing to the facts that the palatine, on either side, reaches back so far, and not a small quadrate, bends inwards towards them and the orbital cavity. Each pterygoid articulates with an elliptical facet at the base of the rostrum, just without the orifice to the Eustachian tube.

Differing in no essential particular, we find the hyoid apparatus much as it is in this group generally. We find all the elements to be delicately constructed bones—the basi- and uro- hyals have thoroughly ankylosed at the points where they are met on either side by the thyro-hyals. A generous facet is developed to support the cerato-hyals. In my specimen of the chick of the Kildeer plover already alluded to, I find that all the elements that go to make up the lower mandible have thoroughly united even at this early age. No ramal fenestra in this bird, however, is visible, whereas in the mandible of the adult *Podasocys* a spindle-shaped aperture remains throughout life. The posterior angular processes of the lower jaw are slender recurved spiculæ of bone in comparison with the rather massive inturned angular processes, each of which is pierced near its apex with the pneumatic foramen, seen in so many of the class. The rami of the mandible of the mountain plover make a very acute angle with each other, and the upper margins are quite sharp, while they are rounded inferiorly. Other ossifications take place in the head, as the sclerotals and the stapedial plate in the ear.

Of the Axial Skeleton.—Twelve vertebræ are found in the neck of this plover, including the atlas and axis, before we arrive at one in the series that bears a pair of free ribs. Of these twelve vertebræ the atlas is of the most usual form, as found among carinate birds; its cup for the occipital condyle is deficient in bone at the bottom, and carried from there through the superior brim. The axis possesses a knob-like neural spine, while in the third vertebra this process becomes a small compressed square lamina, and in this segment, too, we find an extensive quadrate hypapophysis below, a minute foramen on either side, in the bony plate joining the zygapophyses, and well-developed parapophyses. These features still persist in the fourth vertebra, but the foramen mentioned has so increased in size here that it is reduced to a mere "inter-zygapophysial bar." In the fifth, sixth, seventh, and eighth, the neural spine has disappeared; the hypapophysial plates are longer and shallower; the parapophyses persist as parial and at the same time lateral spines, pointing posteriorly. The remaining four vertebræ of the first twelve show the inter-parapophysial grooves for the carotid vessels, as this occupies the former site of the hypapophysial plate in the vertebræ above, it has here, as a matter of course, disappeared; the neural spines or plates are likewise suppressed; the parapophysial spines, soon to be represented by free ribs, still are seen, and they are so wedged in at the fore end of each of these vertebræ as to form on either side the vertebral foramen for the vertebral vessels. These four vertebræ are the longest in the neck, and their post-zygapophyses, diverging from each other, reach well backwards. In several respects the thirteenth and fourteenth vertebræ are peculiar, and differ from all the rest. They are broader and wider than the first twelve that we have just been examining, and each supports a pair of free ribs with well-developed tubercula and capitula; the second pair, or those on the fourteenth vertebræ, may bear uncinatè processes, situated low down on the rib. The neural spines are still suppressed, but the hypapophyses again make their appearance mesiad and beneath the centra; in the thirteenth it consists of a single plate, while in the fourteenth a lateral offshoot springs from each side of this, so that three lamelliform prongs are present in this segment. A deep pit, with overhanging

brim on each side of the centrum, is for the first time observed as we descend the series in these two vertebræ. It becomes wider and shallower as we pass through the vertebræ beyond, but does not disappear until we pass to those anchylosed segments that are grasped by the pelvic bones.

The succeeding six vertebræ, or the fifteenth to the twentieth inclusive, are all free, being specially characterised by supporting free ribs that articulate with the sternum through the means of sternal ribs. The neural spine is well pronounced in the first (the fifteenth) of this series, but in the remaining five it is a lofty median crest, each interlocking, before and behind, at the angles at the summit with a kind of arrow-head joint. Transverse processes stand out horizontally from these vertebræ, and needle-like metapophyses connect them in several instances, though they do not quite meet in every case. The fifteenth and sixteenth vertebræ retain the hypapophysial processes, being triple in the former, as in the vertebra we described as succeeding it, while in the latter it has become single again, long and triangular. In the remaining four it is entirely absent. The vertebral ribs are quite slender, and all support long unciform processes, that in the adult articulate with their posterior borders; the costal ribs become longer as we proceed backward in the direction of the pelvis.

As in so many of the class, the following vertebræ, twelve in the present instance, have firmly united to form one bone. During ordinary maceration of the skeleton of *Podasocys* this bone becomes entirely detached from the pelvic bones on either side of it, whereas no amount of maceration would ever show the landmarks among the original vertebræ. The first four of these throw out their lateral processes as abutments against the spreading ilia, while above we observe the confluent neural spines which gradually merge into the common surface about over the centrum of the fifth vertebræ. The anterior aspect of the leading vertebra of this "sacrum" possess all the essential parts to articulate with the last free vertebra beyond it; it likewise bears a pair of long and extremely slender but free ribs, that connect below with false sternal ribs that articulate only with the posterior borders of the last pair of true costal ribs. I believe these first four vertebræ correspond to the dorso-lumbar

of Professor Huxley, as described in his *Anatomy of Vertebrated Animals*, for the Sacrum of a Chick. Nervous foramina are found along the entire side of this confluent bone, occurring at the proper intervals between the joints as they existed in the chick. These apertures are double; one being placed immediately above the other, the first pair being the largest of the series, and the last or most posterior pair exceedingly minute, if not sometimes absent.

The next five vertebræ are compressed from above downwards, allowing for a swell in the neural canal within, which is to accommodate an enlargement which here takes place in the myelon. Springing from above, the second, third, and fourth vertebræ of this portion of the bone throw out lateral processes that gently bear against the ilia; these increase in length and interlace at their extremities, and with the extremity of the far stronger process, composed of both rib and transverse apophysis developed on the part of the *fifth* of this series. This abuts against the pelvis opposite the acetabulum, its extremity expanding to increase the surface for this purpose as it does so.

The five vertebræ we have just called attention to, make up the true avian "sacrum," as given us by Huxley in the work already alluded to.

Professor Gegenbaur grants the bird only *two* vertebræ in its sacrum proper, presenting us with diagrammatic sketches where the bone is compared with a like drawing of the sacrum of a reptile.¹ There seems to be a great deal of truth in his view of the matter, too, but authors are still much divided on this question, and it probably will not be definitely settled until many more comparisons have been made. The remaining three coalesced segments of the bone we have under observation have been termed by the eminent ornithotomist, Professor Parker, the "uro-sacral²;" they are considered by Professor Huxley the leading caudals. The centra here contract in size quite rapidly; as we proceed backwards from the enlargement of the sacral vertebræ; they still, however, continue to project their lateral processes against the pelvic bones, the last pair of these offshoots being much stouter than the antecedent ones.

¹ *Elements of Comp. Anat.*, Lond. 1878, p. 434.

² Art. "Birds," *Encyc. Brit.*, 9th ed., vol. iii. p. 179.

In viewing this confluent bone from above in *Podasocys*, we are struck at once by the delicate structure of the outstanding processes, united as they are by a thin and narrow ribbon of bone along their extremities only, this allows large sub-elliptical foramina to occur in pairs throughout the entire length, and accounts for the ease with which the pelvic bones may be detached in the adult. These latter are very thin and of a delicate structure themselves; the ischiatic foramen is closed in, but the slender pubic style fails to meet the ischium, after it springs from its acetabular connection. On the under side of these united bones we observe a bar of osseous deposit, thrown out from a point opposite the ring of the acetabulum to the inner margin of the ilium, where it forms a brace for the process of the fifth sacral vertebræ mentioned above. The ischium is carried backwards to a sharp point, and just above it, where this bone unites with the ilium, a second process quite long and triangular, is seen.

Seven free vertebræ make up the tail of this plover; this includes the oblong pygostyle or the last one of the series.

Upon careful examination I can find no foramina created, either in the bones of the shoulder girdle or in the sternum, for the entrance of air into those parts where pneumaticity constitutes one of the features in many others of the class.

The furculum is the perfect miniature of this bone in a specimen of *Numenius longirostris* which lies before me; the clavicular limbs are of uniform thickness throughout, and only very slightly increased in bulk where they unite, mesiad and below, to support a small quadrilateral hypocleidium. The extremities of the bone above reach backwards in the articulated skeleton to meet the processes coming from the scapulæ, to close in the tendinal passages on either side which exist between these bones and the coracoids. These latter elements of the shoulder-girdle (Plate V. fig. 5, c) are chiefly remarkable for the peculiar little, curved, hook-like processes they develop at their outer angles; their shafts are rather stouter than the lower third of the tibia, and they supply about two-thirds on each side to the articular surface of the glenoid cavities. Above, their heads are bent more than usually forwards.

A scapula (Plate V. fig. 5, s) is fully twice as long as the *shaft*

of a coracoid; curved, broad, and rounded at its posterior extremity, it reaches well back towards the ilium, overlapping the ribs.

My drawing of the *sternum* in fig. 8 of the Plate represents this bone on a three-quartering view, in order to show how characteristically the rounded sides of the body are raised upwards. This fact gives its ventral surface the shape of the bowl of a spoon.

The manubrium (figs. 7 and 8, *m*) is a stumpy process, shaped like a wedge, being notched above and sharp below. Above it the coracoid grooves nearly meet at a point in the mesial plane at its base, while the lateral processes of the same name, of a triangular form, rise well above the superior margin of the bone, to bear along their posterior border the facets for the costal ribs, six on each side.

The xiphoidal extremity of the body of the sternum of *Podasocys* is four-notched, the notches being deep, and giving rise to five processes, a median one, the under surface of which supports the hinder part of the carina, and a pair on each side of it.

The tips of these processes are expanded, which expansions are of such a form as one might expect to find had the notches been at one time foramina, and having increased equally in size in all directions, had at last eaten their way through the posterior margin of the body of the bone.

On the ventral surface of the sternal body we see the lines distinctly marked that divide the spaces occupied by the two chief pectoral muscles. These lines approach the keel, and, at the point where they meet it, it is thickened by additional bony deposits in its substance. As the depth and general dimensions of the keel to a bird's sternum is the most reliable criterion of its powers of flight, were the skeleton alone presented to us, we may safely say, in the present instance, that the mountain plover is a strong flyer, as my knowledge of the bird in nature shows. The carinal angle in front projects well forwards, and its sharp anterior margin is carried up from below into a medium groove above, that is found in that descending pillar of bones, present in nearly all of the class, that comes down in the carinal plate in this situation, from the base of the

manubrium, to spread out below and merge into the general surface (Plate V. fig. 8).

The sternum of this bird, as in the case of the clavicles, looks like this bone reduced of our common long-billed curlew (*N. longirostris*), which also has a 4-notched sternum, but this feature does not always occur in forms of fairly near kin—as Professor Owen tells us—though it is usually the case. This eminent anatomist says—“The woodcock (*Scolopax*) has a pair of notches, with the outer boundary slender and shorter than the broad intermediate tract; the gambets (*Totanus*), avocets, sandpipers (*Tringa*), curlews (*Numenius*), pratincoles (*Glareola*), have the 4-notched sternum. In the godwits (*Limosa*, *Helias*) the medial notches are almost obsolete, and the lateral ones wide. The ‘thick-knees’ (*Ædicnemus*) and bustards (*Otis*) have the 4-notched sternum, the notches being small.”¹

Ossification in this plover is normally extended, as in many other birds, to the plate of the superior larynx, the rings of the trachea, and a few tendons and sesamoids.

Of the Appendicular Skeleton.—The chief point of interest that attaches to the limbs of our plover is that they are absolutely non-pneumatic, both the pectoral and pelvic extremities presenting, in all of the bones that compose them, those characters, after maceration, so well described by Hunter,² when this feature is absent. Other birds more or less related, equally well endowed with the powers of flight, lack this feature in the long bones of the arm and hand, and the leg and foot, as may be seen in *Gallinago* and *Philohela*. All of these bones are shaped as we find them among the majority of this class.

In the *humerus* (Plate V. fig. 6) we find the proximal extremity well expanded, and a strongly-marked curling crest overshadowing the usual site of the pneumatic foramen. The “preaxial ridge” is shorter than we usually find it, that is, it does not extend so far down the shaft; this shortening, however, is not accompanied by any diminution in the height of this ridge.

The shaft of this bone is straight and subcylindrical on section; its distal extremity supports the usual points for ex-

¹ *Anat. and Phys. of the Verts.*, vol. ii., Lond. 1866, p. 26.

² *Observations on the Animal Economy*, Palmer's ed., 8vo, 1837, p. 178.

amination. In addition, we observe a peg-like process just beyond the "oblique tubercle."

The ulna shows the row of osseous papillæ for the quill-butts of the secondary feathers, feebly pronounced; its companion bone of the antibrachium, the radius, is about one-third its bulk.

Between the distal extremities of these bones and the trochlear surface afforded by head of metacarpus, we find the usual pair of free carpal elements articulating in the ordinary manner.

The hand of this plover is a long one, as is the case with others of the *Charadriomorphæ*; the extent of the pinions in plovers being quite a striking feature during the flight of these birds.

The pollex has one joint, the next digit two, and the last, one; there are no claws or spurs in the manus of this bird, as seen in some of the Asiatic forms.

The entire length of the skeletal arm of *Podasocys* measures 14 centimetres—of which the humerus takes 4·4; the ulna, 4·6; the carpus, 0·2; the metacarpus, 2·3; and the two phalanges of index digit, 2·5.

In the *femur* of the lower limb we notice that the head is nearly sessile with the shaft, and placed nearly at right angles to it; on its upper surface the pit for the ligamentum teres is seen. The crest of the great trochanter is sharp and elevated above the general surface of the summit of the shaft. At the inferior extremity the outer or larger condyle falls but a little below the inner one, the groove for the head of the fibula being well cut into it.

Of the two processes on the anterior aspect of the head of the *tibia*, the inner one is of a broad quadrilateral form inclined outwardly, while the external one is a rounded, claw-like, and sharp process, curving downwards.

On the anterior aspect, just above the condyles, an osseous bridge is seen (Plate V. fig. 9, *a.b.*) to confine some of the tendons as they pass to the metatarsal region below.

The *fibula* is a very delicate spicula of bone, reaching down, in the articulated skeleton, only half way to the inferior tibial condyles.

Professor Huxley, in his *Anatomy of Vertebrated Animals*,

when treating of the metatarsus of birds, calls the process at the posterior aspect and proximal extremity of that bone the "*hypo-tarsus*." It here consists of two processes, each grooved for tendons at their summits, with another longitudinal groove lying between them. The inner process is the larger, and sends from its lower portion a sharp ridge of bone that is carried down on the shaft and gradually merges into it.

The pits to receive the condyles of the tibia on the superior aspect of the head of the tarso-metatarsus are deep, and a knob-like apophysis arises between them on the anterior boundary. Just below this a fossa exists, at the base of which a foramen is seen, which pierces the bone behind, to the inner side of the larger process of the hypo-tarsus. Its shaft is long and straight in *Podasocys* and the mid-trochea projects well beyond its fellow on either side. The usual foramen is seen just above its base and to the outer side (Plate V. fig. 10, *no*). I am thus particular with this bone because it is one that constantly falls under the observation of the palæontologist in his studies of fossil forms of birds; and my friend Professor Cope tells me that, perhaps of all others, it seems to be the bone that is preserved in the best condition.

As the hallux of this bird is suppressed, the digits of the foot are supplied with phalanges, from the second to the fourth toe inclusive, with three, four, and five joints respectively. Measuring from the summit of the trochanteric crest of the femur, on a straight line to the apex of the claw of the mid-digit in the skeleton leg of this plover, we find it to be 15·5 centimetres in length. Of this the femur takes 3·0, the tibia 5·6, the metatarsus 4·2, and the mid digit 2·7 centimetres.

Glancing back over the results of our examination of the skeleton of this pluvialine form, we observe that its cranial characters bear out those of the Charadriomorphs, as drawn up by Professor Huxley, differing in no essential particular; slight differences, however, were observed when we came to compare this bird with *Charadrius pluvialis*, in the lacrymal bone, and in the relative size of the ossified prefrontal processes of the ethmoid.

In all other respects its skeleton probably represents, as I have endeavoured to describe it, the type of the true plovers.

DESCRIPTION OF PLATE V.

Fig. 1. Left lateral view of skull of *Podasocys montanus*, life size, in which *pm* refers to the premaxillary; *v*, vomer; *n*, nasal; *ae*, alioethmoidal plate; *t*, orbital septum; *s.f.*, supraoccipital foramen; *g*, os quadratum; *ap*, posterior angular process; *p*, palatine; *mv*, mandibular foramen; *d*, dentary portion of inferior maxilla.

Fig. 2. Superior view of the same skull, life size; same letters signify the same as in fig. 1, with *l*, lacrymal; *m*, maxillary; *f*, supraorbital foramina.

Fig. 3. Basal views of the same skull as fig. 1, life size; mandible removed; letters as before, with *mp*, maxillo-palatine; *pg*, pterygoid; *pp*, basipterygoid process of the sphenoid; *ca*, foramen for carotid artery; *f*, foramen for glossopharyngeal and vagus nerves; *C*, the occipital condyle; *j*, foramen to the sinus canal; *fm*, foramen magnum; *g*, condyloid foramen for hypoglossal nerve.

Fig. 4. Posterior views of the same skull, life size; letters signify the same as in figs. 1, 2, and 3, with *oc*, occipital crest.

Fig. 5. Right scapula and coracoid of *Podasocys montanus*, size of life; *s*, scapula; *C*, coracoid; *g.c.* glenoid cavity.

Fig. 6. Anconal aspect of left humerus, *Podasocys montanus*, life size. The figure also shows where this bone has been rotated from this position (*a*) to a view of its proximal extremity, (*b*) the planes of view perpendicular to the axes of vision being given.

Fig. 7. Inferior view of sternum of *Podasocys montanus*, life size; *M*, manubrium; *c.p*, costal process; *k*, carina; and *i*, *i'*, *i''*, and *i'''*, facets for costal ribs.

Fig. 8. Same bone as in fig. 7, viewed left quartering; letters the same.

Fig. 9. Right leg bones of *Podasocys montanus*, life size; nearly front view; *F*, the fibula; *T*, tibia; *o.b.*, osseous bridge for tendons.

Fig. 10. Right tarso-metatarsus, of the same bird, life size, anterior view; *Ko*, perforating foramen between the tarsal bones; *no*, foramen for anterior tibial artery.

Fig. 11. Anterior view of right femur of the same specimen, life size.

SHORT NOTES ON THE MYOLOGY OF THE AMERICAN
BLACK BEAR (*Ursus Americanus*). By FRANCIS
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LAST May I was fortunate enough to obtain a fine specimen of the American Black Bear, which had been killed by its mate in a bear-pit kept by a notorious character in this city. The bear was a male, and between six and seven years old. He measured, from the tip of his nose to the end of his toes, 7 feet 6 inches, and was in good condition. The brain had been removed when he came into my possession, and, in consequence, the occipital portion of the skull was much mutilated. The following account does not profess to be a complete one of the myology, my attention having been chiefly directed to the muscles of the limbs. In my description of the muscles I have taken human anatomy, with which I am best acquainted, as the standard.¹

NECK.

Sterno-mastoid.—Arises from the upper part of sternum, passes forwards and outwards, and divides into two portions. The outer and most superficial crosses the neck and blends with the *trapezio-deltoid* (*cephalo-humeral*) a short distance above the tendinous intersection between the trapezius and deltoid portion. The inner and larger portion passes forwards and ends in a round tendon, which is inserted principally into the mastoid process, which in the bear is well marked, but has also an attachment to the root of the styloid process in front, and the occipital bone behind.

Sterno-hyoid and *sterno-thyroid* arise together from the first piece of the sternum, but soon separate. Their insertion is much as in man.

Thyro-hyoid is a triangularshaped muscle with the base

¹ I must here acknowledge my great indebtedness to Mr A. W. Clement, V.S., and Messrs Kinloch and M'Guaig, medical students, for the great assistance they rendered me during the dissection.

forwards. It arises from the lateral mass of thyroid cartilage, and is inserted into the great cornu of the hyoid bone.

Omo-hyoid is a narrow ribbon-like muscle which arises from the anterior border of the scapula, passes forwards and inwards, and is finally inserted into the body of the hyoid with the sterno-hyoid. The muscle consists of a single belly, having no intermediate tendon or intersection.

Digastric (stylo-maxillaris) is a large, thick, well-developed muscle, which arises from the root of the styloid process by a round tendon, and is inserted along the under surface of the body of the inferior maxillary bone from the angle to near the symphysis. There is also a small slip of muscle running in the same direction as the digastric, which arises from the mastoid process beneath the levator claviculæ by a flat tendon, which soon develops into a small fleshy belly, and is inserted into the body of the hyoid. This probably corresponds to the *stylo-hyoid*.

Mylo-hyoid.—Much as in man, except that a few of its posterior fibres arise from the mastoid process.

Genio-hyoid.—A very long narrow muscle. Origin and insertion as in man.

Hyo-glossus.—Divided into two portions, one from the body (basi-hyal), and the other from the cornu (thyro-hyal). The middle portion from the lesser cornu (chondrio-glossus) is absent. The two portions are inserted as usual into the side of the tongue.

Stylo-glossus.—Large size, from the base of the stylo-hyal to the side of the tongue, blending with the fibres of the hyo-glossus derived from the thyro-hyal.

Scalenus.—A large mass of muscle arising by a fleshy origin from the transverse processes of the 2nd, 3rd, 4th, and 5th cervical vertebræ, and also by tendinous slips from the 3rd, 4th, and 5th transverse processes; as it passes backwards beneath the subclavian artery it divides into three slips, which are inserted as follows:—(1) the *innermost* is a broad slip which is inserted into the first rib near its cartilage and under the pectoralis minor; (2) the *middle* slip, which is long and narrow, goes back over the side of the thorax, becomes aponeurotic opposite to the 5th rib, and is inserted into the 7th and 8th ribs

beneath the external oblique and rectus abdominis muscles; (3) the *outermost* slip is rather broader than the middle, and also passes back, and has a muscular insertion into the 3rd, 4th, and 5th ribs. Between the two last-mentioned slips the lateral branches of the thoracic nerves appear.

Longus Colli is of large size, and arises as low down as the body of the 6th dorsal vertebra.

A muscle is seen arising from the lateral mass of the atlas, and going to be inserted into the outer tubercles of the transverse processes of the 3rd, 4th, 5th, and 6th vertebræ. This muscle is of considerable size, and sends a small slip back to be attached to the inner tubercles of the transverse processes of the 6th and 7th cervical vertebræ.

FORE LIMB.

Brachio-lateral subcutaneous muscle.—On removing the skin from the body this muscle comes into view. It is of considerable size, and arises from the fascia of the flank and back, covering the external abdominal oblique and latissimus dorsi muscles. It also has origin from the fascia covering the rectus abdominis, where it passes over the lower costal cartilages. The lower edge is connected with a long narrow strip of subcutaneous muscle, which is derived from the sheath of the penis. From this extensive origin the fibres are collected into a thick, strong band of muscle, which proceeds forwards and receives a thick slip of muscle from the axillary band derived from the latissimus dorsi; the conjoined muscle then crosses the axillary vessels and nerves, and is inserted into an aponeurosis on the outer surface of the great pectoral muscle near its insertion into the humerus. Its lower border also blends with the dorso-epitrochlear portion of the latissimus dorsi.

Pectoralis major.—This muscle is single at its origin, but soon divides into two portions. It arises from nine costal cartilages and the whole length of the sternum, forming a broad triangular mass of muscle which goes outwards and divides into two portions. The broader and deeper portion is inserted into the inner edge of the bicipital groove of the humerus, the narrower and superficial portion into the outer edge of the bicipital groove.

Pectoralis minor.—Triangular in shape. Arises from first piece of the sternum and first costal cartilage, passes across the shoulder, and ends in a tendon which is inserted into the upper end of the outer edge of the bicipital groove of the humerus, in a line with the more superficial portion of the great pectoral. It is quite distinct from the great pectoral.

Trapezio-deltoid (cephalo-humeral).—This muscle is made up of a trapezius and a deltoid portion, separated near the shoulder by a well-marked tendinous intersection. It is a strong thick muscle, which arises from the back of the skull and fascia of the middle of the neck, and at its origin is continuous with the anterior portion of the trapezius; it passes down over the shoulder outside the biceps, and is inserted into the outer side of the middle of the humerus. A short distance anterior to the tendinous intersection it receives a slip from the sterno-mastoid as above mentioned. The levator claviculæ muscle joins it at its tendinous intersection.

Levator claviculæ,¹ is a ribbon shaped-muscle, which arises from the mastoid process and back part of the skull, and at its origin it is closely connected with the sterno-mastoid muscle. It passes back beneath the cephalo-humeral, and ends by being inserted into the deeper portion of the tendinous intersection between the trapezius and deltoid portion of the cephalo-humeral muscle.

*Levator scapulæ major*² arises from the transverse process of the atlas by a fleshy origin, and, enlarging as it passes backwards into a thick bundle of muscular fibres, is inserted into the anterior border of the spine of the scapula near the acromion process; its insertion is conterminous with the anterior portion of the trapezius, from which however it is quite distinct. At its origin it is covered by the cephalo-humeral and levator claviculæ muscles.

Latissimus dorsi, consists of a large sheet of muscle which arises from a small part of the crest of the ilium, the spines of all the lumbar, and the two or three hinder dorsal vertebræ; it

¹ This is the basio-humeralis of Krause, and is probably the homologue of the cleido-mastoid of human anatomy.

² This may be looked upon as a portion of the levator claviculæ, having its insertion shifted to the scapula.

has also an attachment to the lower ribs. As it passes forwards its fibres converge into a tendon, which is inserted into the posterior edge of the bicipital groove of the humerus; before its insertion, it gives off the inner dorso-epitrochlear muscle, and a bundle of fibres which joins the brachio-lateral subcutaneous muscle to cross the axillary vessels as described above.

Dorso-epitrochlear is a thick triangular muscle, which arises from the axillary border of the scapula and the upper surface of the latissimus dorsi; below the latissimus dorsi it receives a portion of the brachio-lateral muscle, and also a slip from the under surface of the teres major. (This latter slip is superficial to the latissimus dorsi). From this multiple origin it passes down the inner side of the limb, and is inserted by aponeurotic fibres into the internal condyle of the humerus and side of the olecranon process of the ulna.

Trapezius is made up of two parts, anterior and posterior. The *anterior* arises as far forwards as the cephalo-humeral, with which it is intimately connected; it also arises from the ligamentum nuchæ and 7th cervical spine, and is inserted into the anterior border of the spine of the scapula. *Posterior* arises by an aponeurosis from the spines of all the dorsal vertebræ, and is inserted into a strong fascia over the infraspinatus and into the end of the scapular spine, near the vertebral border.

Rhomboideus major and minor.—Disposed as in man.

Serratus magnus as in man, with the exception that its anterior portion cannot be accurately differentiated from the *levator anguli scapulæ*.

Levator anguli scapulæ is continuous, with the foregoing of which it is apparently merely the anterior portion. It arises from the transverse processes of the lower six cervical vertebræ, and is inserted as in man.

Splenius colli of small size. It consists of a single slip, which is inserted into the transverse process of the axis.

Splenius capitis of large size, as in man.

Rectus capitis anticus, major and minor.—Very large, powerful muscles.

The *Deltoid* is a powerful muscle, consisting of two portions; the first arises by fleshy fibres from the posterior edge of the

acromion ; the second portion arises principally by aponeurosis from the posterior border of the spine of the scapula, about one-fifth of its origin however, near the acromion process, is muscular. These two portions unite near the humerus, and are inserted into the middle of its outer surface with the deltoid portion of the trapezio-deltoid (cephalo-humeral).

Supra- and infra- spinatus.—Disposed much as in man.

Teres minor not distinguishable from the lower part of the *infra-spinatus*.

Subscapularis.—A very powerful muscle.

Teres major.—A large muscle which takes its origin from the posterior angle of the scapula, the axillary margin being all taken up by the scapular head of the triceps. It sends a slip over the latissimus dorsi to join the dorso-epitrochlear. Inserted as in man.

Coraco-brachialis arise from a rudimentary coracoid process with the short head of the biceps, and passing down the inner side of the humerus is split into two portions. The first (*coraco-brachialis brevis*) is a short muscular slip which is inserted into the inner side of the humerus immediately below the lesser tuberosity and beneath the *teres major*. The second or main portion of the muscle (*coraco-brachialis longus*) continues down the inner side of the limb, and is inserted into the lower part of the internal condyloid ridge of the humerus. This portion is pierced by the musculo-cutaneous nerve.

Biceps brachii is principally made up of the long head which arises from top of glenoid cavity, pierces the capsular ligament, and lies in a very deep bicipital groove. This long head is soon joined by a very small tendinous slip which comes from the coracoid with the *coraco-brachialis*, and represents the second head. The muscle soon expands into a large fleshy belly which ends in a strong tendon near the elbow, and is inserted into the bicipital tubercle of the radius. This tendon gives off a very strong bicipital fascia which covers the brachial artery.

Brachialis anticus has its origin external to the insertion of the deltoid, as high up as the capsular ligament of the shoulder. It is closely connected with the external head of the triceps ; it covers the front of the humerus, and is inserted into the coronoid process of the ulna. There is a tendinous slip between it and

the supinator longus, and it gives a muscular fasciculus to the flexor carpi radialis.

Triceps.—This is a very large powerful muscle which arises by four heads :

a. Scapular head is of enormous size, and arises from the whole length of the posterior (axillary) border of the scapula, and from a ridge or second spine in the infra-spinous fossa, which separates it from the infra-spinatus :

b. Outer head has a tendinous origin from the humerus immediately below the outer tuberosity :

c. Internal head is of small size, and arises from the side of the shaft of the humerus internal to the upper insertion of the coraco-brachialis :

d. The Fourth head is attached to the posterior edge of the external condyloid ridge above the anconeus. The scapular head, which is by far the largest, first unites with the outer head, then these two are joined by the internal head, and finally, just above the elbow, the fourth head joins the other three, forming a common muscle, which is inserted into the olecranon process of the ulna.

Anconeus.—Small in size, arises below the fourth head of the triceps, and is inserted into the external surface of the olecranon as in man.

Pronator radii teres.—Disposed much as in man, has no origin from the ulna, and is inserted into the radius almost as low down as the styloid process. Is a long, narrow muscle.

Flexor carpi radialis.—As in man.

Flexor carpi ulnaris is divided into two portions ; *one* arises from the inner edge of the olecranon and posterior ridge of the ulna, ends in a tendon about the middle of the fore-arm, and is inserted into the pisiform bone ; *the other* arises in common with the sublimis digitorum from the internal condyle of the humerus, and is inserted into the pisiform bone and annular ligament.

Palmaris longus.—Absent.

Flexor sublimis digitorum has no radial origin as in man, but arises solely from the internal condyle and intermuscular septum. It is a well-developed muscle, which, after sending a fasciculus to the annular ligament, divides into three slips ; (1) the most superficial and middle slip divides into three tendons

which go to 2nd, 3rd, and 4th digits; (2) the inner slip ends in a tendon which goes to the 5th digit, and also sends a fasciculus to the pisiform bone; (3) the deepest slip ends in a tendon which crosses the middle slip and is inserted into the terminal phalanx of the 1st digit. The tendons to the four inner digits are perforated by the tendons of the profundus digitorum.

Flexor profundus digitorum is a very large muscle, and arises by two heads, *one* superficial in common with the other muscles from the internal condyle; the *other*—the deeper head—arises from the anterior surface and posterior ridge of the ulna, from the interosseous membrane, and from the anterior surface of the radius below and internal to the oblique line. These two heads end in two flat tendons which, opposite the carpus, unite to form one thick broad tendon; the latter passes under the annular ligament and divides into five tendons going to be inserted into the terminal phalanges of the digits. The four inner tendons perforate the corresponding tendons of the sublimis digitorum. The radial edge of the common tendon is well rounded, and is directly continuous with the radial origin, having an appearance similar to the flexor longus pollicis of man. Arising from the superficial portion near its junction with the deep are two small muscular slips which, passing under the annular ligament, end in two slender tendons which blend with those of the profundus going to the 3rd and 4th digits.

Pronator quadratus.—Disposed as in man.

Lumbricales.—Four in number, attached to the four inner tendons of the deep flexor, and arranged as in man.

Abductor and Opponens pollicis of small size, but quite distinct muscles.

Flexor brevis pollicis of considerable size, arranged much the same as in man.

Abductor minimi digiti, Opponens minimi digiti, and Flexor brevis minimi digiti.—The two first of large size, the last very small. Disposed as in man.

Interossei, of small size.

Supinator longus.—A muscle of small size. Arranged as in man.

Supinator brevis.—Arises from the external condyle, external lateral ligament, and orbicular ligament, but has no origin from

the ulna. The shape is oblong, and its insertion covers three quarters of the upper part of the radius, posterior to and above the oblique line.

Extensor carpi radialis longior et brevior.—These muscles are not differentiated completely, but have a common origin from the external condyloid ridge and external condyle of the humerus. The conjoined muscle is of small size, and, after passing down the outer side of the arm, ends near the carpus in two tendons, which, after going beneath the tendon of the m. ext. ossis metacarpi, and through the annular ligament, are inserted into the bases of the second and third metacarpal bones respectively.

Extensor communis digitorum, arises from the external condyle of the humerus, and divides into four tendons, which go to the 2nd, 3rd, 4th, and 5th digits.

Extensor minimi digiti arises from the external condyle in common with the preceding muscle, and ultimately divides into three tendons which are distributed to the 3rd, 4th, and 5th digits. This muscle is of considerable size and much larger than the *communis digitorum*.

Extensor carpi ulnaris is a large muscle, which arises from the external condyle of the humerus and posterior ridge of the ulna, in common with the flexor ulnaris and flexor profundus; it ends in a broad flat tendon, which is inserted into the base of the 5th metacarpal bone and sends a slip to the pisiform bone.

Extensor ossis metacarpi pollicis.—This is the largest muscle on the back of the fore-arm, and is bipenniform. It arises from the posterior surface of the radius as low down as the insertion of the supinator brevis, from the radial side of posterior surface of the ulna, reaching from the olecranon to the styloid process, and from the interosseous membrane. It has also an origin from the orbicular ligament, and is connected with the supinator longus. From this extensive origin the muscle passes downwards and outwards, and ends in a strong tendon, which, after passing through a special compartment in the posterior annular ligament is inserted into the base of the first metacarpal bone.

Extensor primi internodii pollicis.—Absent, or rather not differentiated from the extensor ossis metacarpi.

Extensor secundi internodii pollicis is a small muscle, which arises from the posterior surface of the ulna superficial to the m. ossis metacarpi, and ends in a long slender tendon, which is inserted into the last phalanx of the 1st digit.

MUSCLES OF THE TRUNK.¹

External abdominal oblique, arises from the lower ten ribs (5-14). Insertion as in man.

Internal abdominal oblique.—Origin from the 13th and 14th ribs, crest of the ilium, and the whole of Poupart's ligament; insertion as in man, except that its aponeuroses all pass over the rectus.

Transversalis, attached to the lower six ribs and whole length of Poupart's ligament and crest of the ilium. Its tendon splits to enclose the rectus.

Rectus abdominis is a well-developed muscle, which reaches from the os pubis to the first costal cartilage. It is attached to all the costal cartilages, and opposite the second becomes tendinous;² as the tendon passes over the first intercostal space it receives some fibres from the first external intercostal muscle.

Pyramidalis, a large well-developed muscle.

Psoas.—The psoas arises from the transverse processes and bodies of the three last dorsal and all the lumbar vertebræ except the last; when it reaches the sacrum it divides into two parts, superficial and deep; the superficial (p. parvus) goes to be inserted, by a strong tendon, into the ilio-pectineal line and spine of the pubis; the deeper portion (p. magnus), which is the larger, joins the *iliacus* muscle about the middle of the ilium, and is inserted with it into the lesser trochanter.

Iliacus, arises from the inner surface of the ilium and is of small size; it is separated from the *psoas* by the anterior crural nerve; after it is joined by the *psoas* it is inserted with it into the lesser trochanter of the femur.

Quadratus lumborum, a muscle of large size, disposed as in man.

¹ Having accidentally lost my notes on the dissection of the deeper muscles of the back and perineum, I omit a description of them altogether.

² Meckel describes the rectus of bears, as tendinous from opposite the 7th and 8th ribs, and again muscular as it passes over the first intercostal space and then becoming again tendinous. In the specimen I am describing the rectus was muscular up to the 2nd rib.

HIND LIMB.

Sartorius consists of a broad sheet of muscle arising from the iliac crest, and covers the greater portion of the anterior surface of the thigh. Its outer fibres end in a strong fascia covering the thigh, which has a special insertion into the patella; the inner fibres of the muscle pass downwards and inwards to be inserted into the tibia below the inner tuberosity.

Pectineus arises from the ilio-pectineal line, external and anterior to the insertion of the superficial psoas, and also from the capsular ligament of the hip. It is inserted into the femur below the lesser trochanter.

Rectus femoris.—Arises by a broad, thick tendon from the upper and outer part of the rim of the acetabulum; as it passes down the front of the thigh it is joined by the vasti muscles and inserted into the patella. It is a comparatively small muscle.

Vastus Externus and Internus.—Large powerful muscles which arise from the linea aspera and envelop the thigh, they are inserted with the rectus into the patella.

Gracilis, disposed as in man, a very broad thin sheet of muscle.

Adductor.—This large muscle consists of two portions—a greater and a less. The *greater* consists of a large sheet of muscle which arises from the rami of the pubis and ischium, and is inserted into the femur from a little below the lesser trochanter to a little above the internal condyle; the *lesser* is a narrow ribbon-shaped muscle, which arises from the tuberosity of the ischium in common with the semi-membranosus, and is inserted into the upper part of the internal condyle of the femur and adductor tubercle; a little before its insertion it joins the *greater portion*.

Tensor fasciæ is of large size, and disposed as in man.

Extensor communis digitorum arises by a round tendon from a deep pit in the front of the external condyle of the femur, a little external to the origin of the popliteus. This tendon then proceeds downwards beneath the capsule of the knee-joint, surrounded by a synovial sheath and grooves, the space between the head of the fibula and external tuberosity of the tibia; it soon develops into a large-bellied muscle, which has some

fascial attachments to the peronei muscles and tibialis anticus; it is fleshy down as far as the ankle-joint, where it becomes tendinous. The tendon passes through a sling of fascia, and divides into two slips over the tarsus. The outer subdivides into three tendons, which go to the 2nd, 3rd, and 4th toes, and the inner slip, which is of large size, goes to the 1st toe.

Tibialis anticus has its origin from the outer surface of the tibia and the interosseous membrane for its whole length, and ends in two tendons, the greater of which is inserted into the under surface of the base of the first metatarsal bone, the lesser into the upper surface of the base of the same bone.

Extensor brevis digitorum arises from the dorsal surface of the tarsus and annular ligament, and divides into four tendons which go to the four inner toes as in man. The one going to the 1st toe is the largest.

Interossei (Dorsal).—Very small, four in number, arranged as in man.

Glutæus maximus, a muscle of fair size, arises from the posterior part of the iliac crest, by a tendinous origin and by fleshy fibres from the side of the sacrum and the great sacro-sciatic ligament. From this extensive origin the muscle passes downwards and outwards over the great trochanter, and is principally inserted into a strong fascia which covers the upper and outer surface of the thigh. It is also inserted into the femur below and internal to the great trochanter.

Glutæus medius arises from the posterior surface of the ilium between crest and curved line, and is inserted as in man.

Glutæus minimus is divided into an upper and lower portion, both pyriform in shape, and separated by a well-marked cellular interspace; the *upper portion* arises from the lower border of the great sacro-sciatic notch, and is inserted into the anterior border of the great trochanter by a round tendon; the *lower portion* arises from the surface of the ilium below the origin of the glutæus medius, and is inserted also by a round tendon into the outer border of the great trochanter.

Pyriformis, small size, disposed as in man.

Obturator internus and Gemelli.—Well-developed muscles, and arranged as in man. The gemelli are especially large, and quite distinct muscles.

Quadratus femoris.—A muscle of good size, and arranged as in man.

Obturator externus arises from the whole outer surface of the obturator membrane and from the surrounding bone, and is inserted as in man.

Biceps femoris is the largest muscle on the posterior aspect of the thigh. It is triangular in shape, and arises from the tuberosity of the ischium, anterior to the semi-membranosus; it also arises from the strong fascia covering the glutæus maximus. From this origin a huge fleshy muscle is soon developed, which passes down the thigh in an outward direction, covering most of the deeper muscles, and is inserted into the fascia of the hind limb from the middle of the thigh to the os calcis; it is also inserted by a round tendon into the os calcis. This tendon cannot be separated easily from the fascia above mentioned, as it forms its inner edge. About the middle of the limb it is attached by means of the fascia into the side of the patella and outer tuberosity of the tibia.

Tenuissimus.—This is a delicate ribbon-shaped muscle, which arises beneath the biceps from the fascia covering the ischial tuberosity. It passes down the limb, beneath and internal to the biceps, and ends in the fascia a short distance above the ankle.

Semi-tendinosus arises from the ischial tuberosity, posterior and superficial to the biceps, passes down the inner side of the leg, and ends in a round tendon which is inserted immediately below and beneath the gracilis, into the inner side of the tibia near the tubercle.

Semi-membranosus is a large muscle, which arises by a broad origin from the inner and ventral surface of the tuberosity of the ischium. It soon divides into two portions, the lower and posterior part being inserted into a groove on the posterior surface of the inner tuberosity of the tibia, as in man. The upper and anterior part, which is the larger, passes down and out to join the great adductor, as described above. Its fibres can be traced to the upper part of the inner condyle of the femur.

Gastrocnemius (Left Side).—This muscle arises by three heads—*outer, middle, and inner*. The outer and middle heads arise together from the posterior surface of the outer condyle of the

femur; the inner head arises from the posterior part of the inner condyle by a round tendon. These three heads develop into three large fleshy bellies, which throughout their course remain quite distinct. The middle belly is the largest, and ends in the proper tendo Achillis, which is inserted into the os calcis; the *outer* and *inner* bellies overlap the middle, and are continuous in the middle line with one another by means of a strong aponeurosis which covers the tendon of the middle belly. The outer belly has also a special attachment to the os calcis.¹ The gastrocnemius is quite distinct from the soleus.

Soleus arises only from the upper and back part of the fibula by a round tendon, and also from the fascia in the outer side of the leg. It proceeds down as a well-developed muscle, and is inserted into the os calcis beneath the gastrocnemius.

Popliteus.—Disposed as in man.

Flexor longus digitorum consists of two portions. The larger (*flexor fibularis*) is a bipenniform muscle which arises from the whole posterior surface of the fibula, from the interosseous membrane, and from the posterior surface of the tibia in common with the *tibialis posticus*. It is muscular down to the ankle-joint and ends in a stout tendon, which, after grooving the astragalus and os calcis, as the flexor hallucis does in man, is joined by the smaller portion (*flexor tibialis*). The conjoined tendon then divides into five slips, which go to the five toes; the outer four perforate the tendons of the short or superficial flexor. The smaller portion (*flexor tibialis*) arises from the posterior surface of the tibia, passes down the back of the leg, and finally ends in a round tendon, which goes over and behind the tendon of the *tibialis posticus*, and then through a deep groove in the inner malleolus to the sole of the foot, where it joins the flexor fibularis. The flexor fibularis is by far the larger of the two portions, the tibial portion being merely an accessory slip.

Tibialis posticus has its origin from the tibia, external to the flexor tibialis and intimately connected and blended with the

¹ The above description is taken from the dissection of the left limb. In the right limb the outer belly was quite separate, except at its origin, from the other bellies, and had no insertion into the os calcis directly, but blended with the fascia into which the biceps was inserted. I looked upon it as a very large *plantaris*, as no other muscle corresponded to the *plantaris*.

flexor fibularis. After grooving the inner malleolus, its tendon is inserted into the scaphoid bone.

Flexor brevis digitorum arises from the inner tuberosity of the os calcis, and divides into four tendons, which are pierced by the deep flexor and go to the four outer toes.

Accessorius arises by a single fleshy head from the outer surface of the os calcis, and is inserted into the deep tendon before its division.

Flexor brevis pollicis and *Adductor pollicis*.—Disposed as in man, but of small size.

Flexor brevis minimi digiti, from the cuboid bone, divides into two heads, in each of which is a large sesamoid bone, is inserted into proximal phalanx of 5th toe.

Adductor minimi Digiti.—From the sheath of the long peroneal muscle, and inserted into the 5th toe with the inner head of flexor.

Lumbricales.—Arranged as in man.

Peroneus longus.—A long slender muscle arising from the upper and back part of the head of the fibula by a round tendon, passes down the leg and ends in a round tendon which passes in front of the external malleolus, grooving it deeply. It then goes over the os calcis and the tendons of the other peroneal muscles, and after grooving the cuboid crosses the sole of the foot to its inner side, to be inserted into the base of the first metatarsal.

Peroneus brevis arises from the outer surface of the fibula, and ends in a tendon, which passes behind the external malleolus and beneath the long peroneal tendon to be inserted into the fascia covering the 5th metatarsal bone and the proximal phalanx of the 5th toe.

Peroneus quinti digiti is a small muscle arising from the upper and outer half of the fibula. It ends in a slender tendon, which is inserted into the base of the 5th metatarsal bone.

Anatomical Notices.

TOTAL ABSENCE OF THE LEFT LOBE OF THE THYROID BODY. By WILLIAM J. GOW, *Student, St Bartholomew's Hospital, London.*

IN dissecting a body lately, which was that of an old woman, apparently between 60 and 70 years old, it was found, on examining the front of the larynx, that the isthmus and left lobe of the thyroid gland were totally absent. The inferior and superior thyroid arteries on that side were exceedingly small, but each of them sent a slender branch to the place where the missing lobe should have been. The right lobe was not at all larger than usual, and showed no signs of ever having been united across the middle line, the borders being remarkably well defined. The remains of the thymus gland seemed larger than usual.

NOTE RESPECTING THE COURSE OF THE FLEXOR LONGUS DIGITORUM PEDIS. By SINCLAIR WHITE, M.D., *Demonstrator of Anatomy, Sheffield Medical School.*

IN some of our text-books on Anatomy a mistake occurs which I will endeavour to point out. I refer to the description given of the course of the tendon of the flexor longus digitorum.

Gray says of the tendon:—"It then passes obliquely forwards and outwards beneath the arch of the os calcis into the sole of the foot."

Quain describes it as follows:—"It is then directed under the arch of the os calcis obliquely forwards and outwards into the sole of the foot." Now, if by the arch of the os calcis is meant the cavity between the sustentaculum tali and inner tubercle of that bone, then I hold the descriptions quoted above are wrong.

Having examined a considerable number of limbs with regard to this point, I find that in no instance does the tendon of the flexor longus digitorum pass beneath the sustentaculum tali, its course being downwards and forwards over the inner surface of the astragalus and internal lateral ligament of the ankle-joint, in most cases grooving the upper part of the inner margin of the sustentaculum, and, in a few, passing above and in front of that process without touching it or any part of the os calcis in its course.

A glance at the articulated bones of the leg and foot will be quite sufficient to convince anyone of this. It will be seen that the groove on the back of the internal malleolus in no way corresponds with the concavity of the arch of the os calcis, and that the tendon passing

down the groove on the back of the malleolus, could not gain the under surface of the arch, except by crossing over the prominent inner margin of the sustentaculum tali, and the tendon of the flexor longus pollicis, which lies immediately underneath that process; but the tendon of the flexor longus pollicis is not crossed by that of the flexor longus digitorum until the anterior margin of the os calcis is reached, so that the latter tendon must be internal to it behind that point. Inspection, however, of the recently dissected parts is the best proof.

I have demonstrated this point to my class for some time, and should not have thought of publishing this note on it had it not been that, on more than one occasion, students complained to me that examiners have insisted that the tendon in question passes underneath the arch of the os calcis.

THE OS CENTRALE IN THE HUMAN CARPUS.

In the last volume of this *Journal*, Jan. 1883, two contributions on variations in the bones of the human carpus appeared, the one (p. 244) by Prof. Turner, the other (p. 253) by Dr R. J. Anderson of Belfast. In both of these communications, the occasional presence of an os centrale similar to the bone found in the carpus of the Orang and some other apes was considered. Since these papers appeared, Prof. Wenzel Gruber of St Petersburg, who is the highest authority on this question, has published in Heft iv. of his *Beobachtungen aus der menschlichen und Vergleichenden Anatomie*, Berlin, 1883, an account of the cases which he had seen subsequent to those previously recorded by him, and has given a general resumé of the whole series of specimens which have come under his notice.

Between October 1868, when he first recognised the os centrale in the human carpus, to the end of September 1882, Gruber has seen this bone thirteen times, eight on the right side, five on the left. Moreover, he has found in twenty-two cases traces of the existence of the centrale in its separate condition at an earlier stage of life, marked either by a fissure or furrow on the navicular (scaphoid) bone. These results have been obtained from the examination of 3707 fresh hands and 1422 hands either in the skeleton or separate navicular bones, altogether 5129 specimens. The centrale has its position in the centre of the radial part of the back of the carpus, between the two rows of bones, and only in exceptional cases does it reach the palmar aspect. It lies between the scaphoid, trapezoid, and os magnum, subject however to two modifications. In the first kind it is situated in relation to the border of the scaphoid, between the digital surface and the articular facet of the ulnar surface, and always articulates with the trapezoid, which has therefore an abnormal ulnar facet on its brachial aspect; in the second kind its seat is on the dorsal ulnar angle of the scaphoid, and it either may or may not articulate with the trapezoid. The centrale of the first kind occurs more than twice as frequently as that

of the second ; its form is a compressed tetrahedron or a compressed pyramid ; that of the second is a segment of an oval body. The first kind varies much in its dimensions, and presents examples of the largest and smallest size, whilst the second kind gives only the intermediate sizes. The first kind as a rule has only a border on the back of the carpus, seldom a surface, and for the most part is concealed in the carpus ; the second kind has always a dorsal surface, and is therefore distinctly recognisable on the back of the carpus.

Gruber then discusses the condition of the carpus in the human embryo, with reference to the observations of Henke, Reyher, Rosenberg, and Kölliker as to the presence in the embryo of the third month of a distinct nodule of cartilage, situated between the first and second rows of the carpalia, and representing the os centrale. Henke and Reyher think that this nodule fuses with the cartilaginous scaphoid, and that the scaphoid bone is therefore compounded of the radiale and the centrale. Rosenberg and Kölliker again consider that the centrale disappears, and that the scaphoid consists only of the radiale. Gruber considers that his macroscopic researches into the composition of the carpus support the view that the scaphoid may in exceptional cases be compounded of the radiale and the centrale, but that as a rule it consists of the radiale alone. He believes that all the scaphoid bones with a parallelogrammatic form, and those of a biscuit shape, which possess a tooth or small process on or near the dorsal ulnar angle, are compounded of radiale and centrale, whilst all other scaphoids are formed solely of the radiale. When the centrale exists as an independent element, it represents therefore an early condition of the human carpus, which as a rule becomes greatly modified as development advances.

In the Gorilla, Chimpanzee, and other apes where the centrale is wanting in the carpus, the scaphoid possesses a transverse superficies dorsalis ; in the Orang, Hylobates, Cynocephalus, &c., which possess an os centrale, this dorsal surface is wanting in the scaphoid, and in its place the line of the joint between the scaphoid and centrale occurs, so that the navicular corresponds to the upper or proximal part, the centrale to the lower or distal part, of the navicular of the Gorilla or Chimpanzee. In man the centrale corresponds either to the more or less large ulnar section of the distal portion of the scaphoid, or has little or nothing to do with it. Not only can the supernumerary os centrale of man, but also the constantly present centrale of certain mammals, become fused with the scaphoid. Gruber has seen partial fusion in an old male *Cynocephalus hamadryas*, and complete fusion in an old male *Cynocephalus mormon*.

Fig. 1.



Fig. 8.

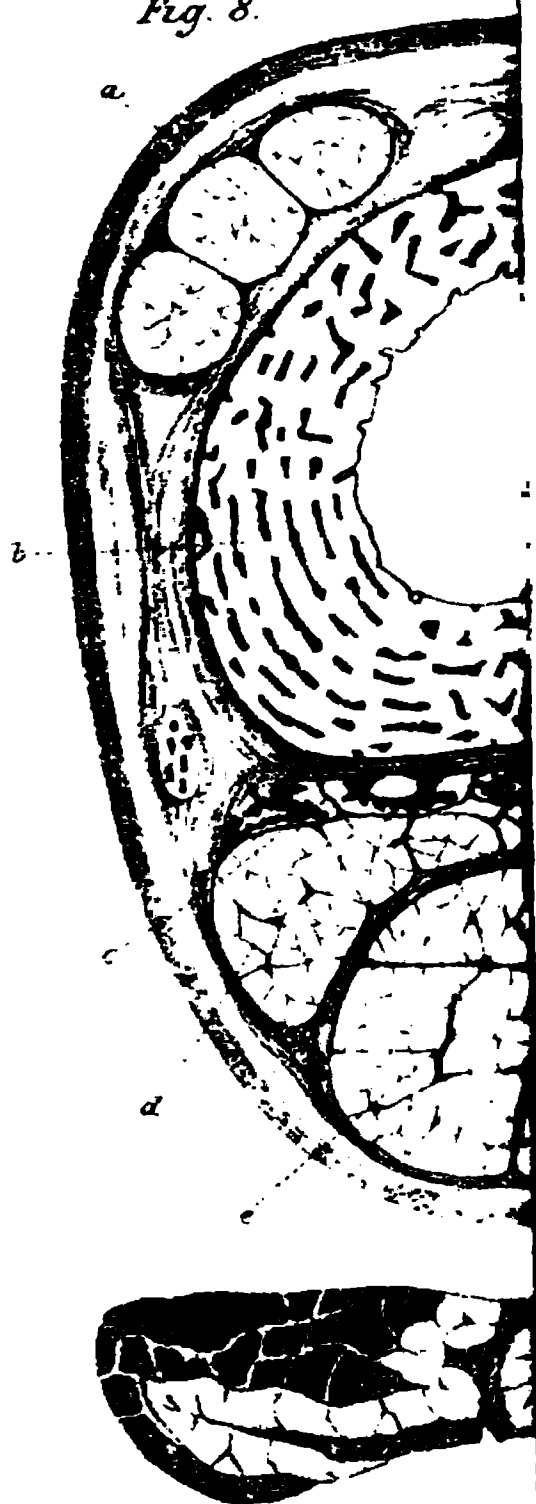


Fig. 1.

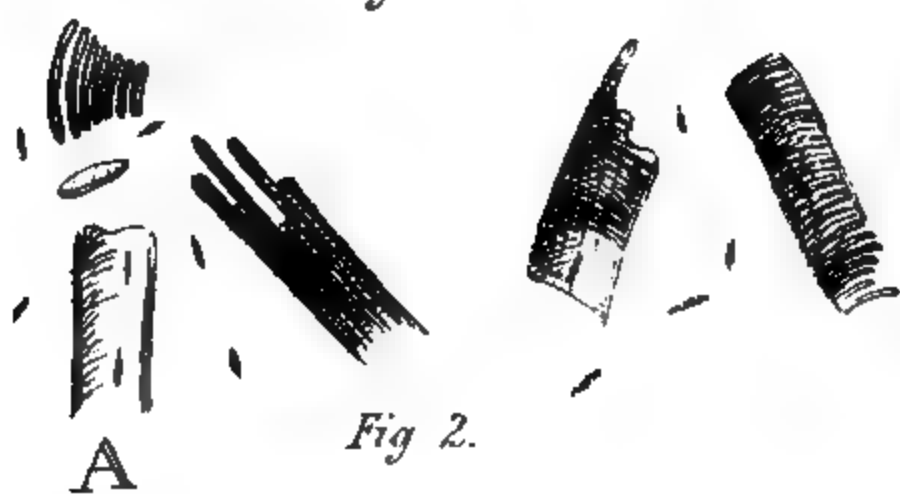
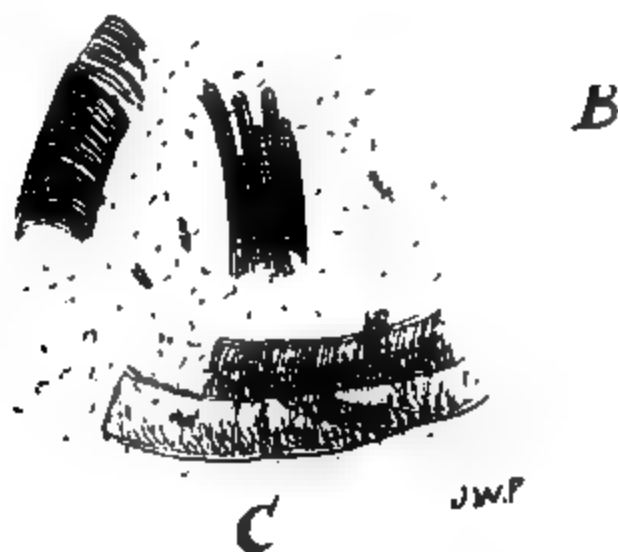


Fig 2.



J.W.P.

Fig. 1





Fig 6



Fig 2.



Fig 4.

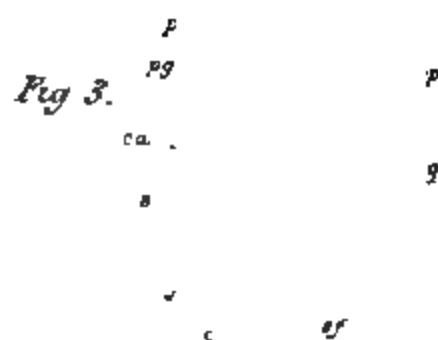


Fig 3.

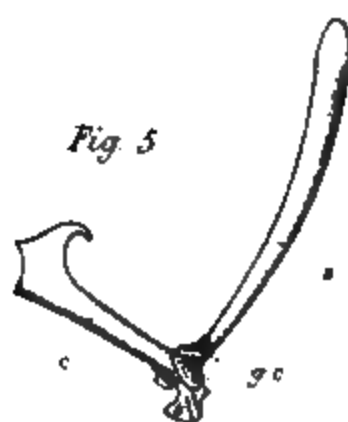


Fig 5.

Fig

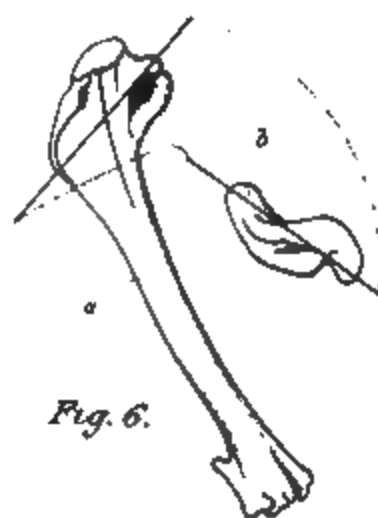


Fig. 6.

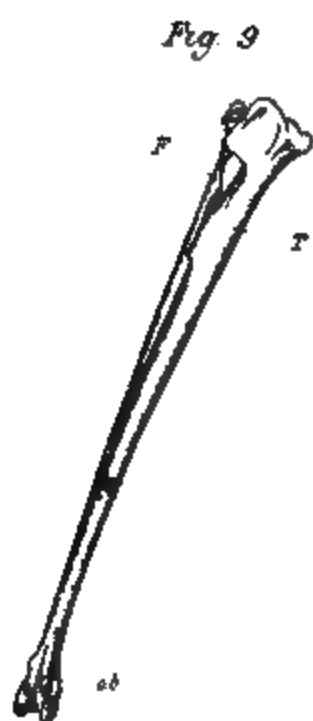


Fig 9.

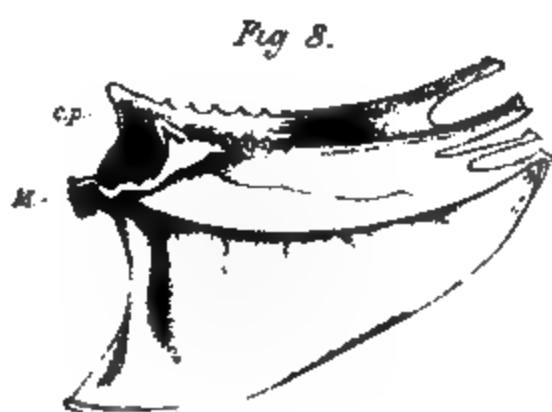


Fig 8.

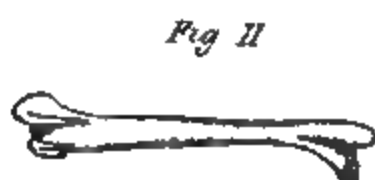


Fig 11



Fig 10.

R. W. Stedman del.

T. Hutch, Litho. Edin.

Journal of Anatomy and Physiology.

ON CERTAIN ABNORMAL CONDITIONS OF THE REPRODUCTIVE ORGANS IN THE FROG. By A. MILNES MARSHALL, M.D., D.Sc., M.A., *Fellow of St John's College, Cambridge, Beyer Professor of Zoology in Owens College.* (PLATES VI. and VII.)

Two winters ago, in the course of the ordinary laboratory work of the Owens College, a male frog was met with in which the Müllerian ducts, instead of being as usual straight and very slender tubes, were of considerable size and much convoluted. In the following winter a second and much more remarkable case occurred, in which the Müllerian ducts attained the full dimensions of the adult female oviducts, and in which the testes were strongly pigmented and contained imbedded in their substance what appeared to be true ova.

Quite recently two additional specimens have come into my hands, the first a male frog in which the right testis is almost completely absent, the left one of unusual size, and the Müllerian ducts larger than usual, and convoluted; the second, a case in which the ducts are of the ordinary female type, and in which there is an ovary on the left side, and on the right a testis, or rather hermaphrodite gland. For the latter specimen I am indebted to the courtesy of Professor Haddon, of Dublin, who had intended describing it himself, but learning that I was interested in the point generously handed over the specimen to me.

As the occurrence of hermaphroditism, actual or potential, in vertebrates is of considerable interest, and as such abnormalities in Amphibia acquire special importance from the relations of the group to higher vertebrates, I have thought it well to place on record descriptions and figures of these cases, especially as a

more minute study of them has revealed some unexpected and instructive points.

DESCRIPTION OF THE SPECIMENS.

I propose to distinguish the four specimens, which are all of *Rana temporaria*, as A, B, C, and D respectively, and to deal first with the anatomy and then with the histology of the parts concerned.

I.—*Anatomy.*

Frog A.—The condition of the parts in the first specimen is shown in Plate VI. fig 1; the bladder and greater part of the viscera having been removed, as well as the right testis and fat body, while the left testis, *t*, has been turned over with the fat body to the right side, so as to show the vasa efferentia passing from the testis to the kidney.

The testes are of normal shape, are free from pigment, and are slightly larger than usual; the left testis, the one figured, measuring 16 mm. in length by 8.2 mm. in width and 6.2 mm. in thickness, and slightly exceeding the right one in size.

The fat bodies are of great size, and more firmly adherent than usual to the testes, the union extending some little way down the dorsal surface of the testes, as shown in the figure.

The Müllerian ducts (fig. 1, *m.*) are much convoluted tubes, with firm walls dotted with pigment cells along the greater part of their length, and having an average diameter of 1 mm. Each duct commences in front with an open mouth situated in the normal position close to the root of the lung. The lower end of the duct is dilated for a length of about 9 mm., forming a thin-walled sac, 3 mm. in width, with strongly pigmented and dilatable walls. This sac, which clearly corresponds to the uterine dilatation of the oviduct in the normal female frog, runs alongside of, and is fused with the lower end of the Wolffian duct; the cavities of the two ducts are, however, quite distinct from one another, and have separate openings into the cloaca.

The lower end of the Wolffian duct (fig. 1, *v.s.*), below the kidney is slightly dilated, forming a vesicula seminalis similar to that of the normal male frog but of much smaller size, having a width of only 2 mm.

The condition of the ducts in the frog A is, on the whole, intermediate between those of the normal adult male and female frogs. The Müllerian duct is much more highly developed than in the normal male, but less so than in the normal female; it agrees very closely, both as to actual size and extent of convolution, with the oviduct of a female frog at the end of the first year. The Wolffian duct differs from the female type in the possession of a vesicula seminalis—which, however, is of much smaller size than in the normal male frog. The condition of the vesicula seminalis will be again referred to when considering frog C. In having four separate and independent openings into the cloaca for the Müllerian and Wolffian ducts of the two sides, the frog A resembles the normal female frog and differs from the male.

Frog B.—The various organs with which we are concerned are represented *in situ*, and of the natural size in fig. 2, while fig. 3 shows the right testis, with the fat body attached, removed from the body and magnified three diameters.

The testes are rather elongated, and slightly irregular in shape, though of normal size. Each presents along its outer border an irregular band of black pigment, commencing at the upper or anterior end and extending about two-thirds of its length. At the anterior end of each testis is a small clump of spherical bodies, which are strongly pigmented, and closely resemble ova in appearance. These are better seen in fig. 3, in which the fat body has been slightly displaced. The extreme anterior end of the testis has the form of a small lobe (fig. 3, *a.*), hidden in fig. 2 by the fat body, and separated by a slight constriction from the main body of the testis. The lobe is pigmented, and presents on its surface a number of slight knob-like projections, having an average diameter of .3 mm. Behind this anterior lobe, and between it and the main mass of the testis, there is on the ventral surface a group of four or five strongly pigmented spherical projections, attaining a diameter of 1 mm., and bearing, as already noticed, a striking resemblance to ova. In the left testis (fig. 2) this anterior lobe is not present, and the pigmented projections extend somewhat further down.

The vasa efferentia are normal on both sides; and the

fat bodies, though of considerable size, present no special features.

The Müllerian ducts (fig. 2, *m.*) agree closely with those of an ordinary adult female. Each is a very much convoluted tube with thick opaque white walls containing abundant mucus, which swells up considerably in water. Commencing with an open mouth in the normal position, close to the root of the lung, the tube runs back, increasing in size, and attaining at its widest part a diameter of 3 mm.: the terminal part dilates to form a thin-walled sac (fig. 2, *m.*), about 14 mm. long and 4 mm. wide, with pigmented and longitudinally plicated walls clearly corresponding to, though rather smaller than, the so-called uterus of the female frog.

The Wolffian duct (fig. 2, *v.s.*) is dilated below the kidney, and is fused for the last 5 mm. of its length with the uterus. As in frog A, however, the cavities of the two ducts are quite distinct from one another, and their openings into the cloaca separate, as in the female frog. In fact, in frog B the ducts are almost completely of the normal female type, from which they differ merely in the slight dilatation of the Wolffian duct, the fusion of the lower ends of the Wolffian and Müllerian ducts on each side, and the comparatively small size of the uterine dilatation of the Müllerian duct. The histological peculiarities of the testes themselves will be noticed later on.

Frog C.—In this case the left testis is much larger than usual, measuring 13 mm. in length by 9·2 mm. in width and 7·8 mm. in maximum thickness. It is somewhat pear-shaped, and strongly pigmented on the surface. The right testis is almost completely absent, being represented merely by a slight oval thickening of the peritoneum, 2·5 mm. long by ·8 mm. wide, and consisting mainly of a mass of fat cells. The vasa efferentia are normal on the left side, absent on the right; and the fat body is of great size on both sides.

The Müllerian ducts on both sides resemble those of frog A, but are slightly smaller. They are convoluted tubes, having an average diameter of ·4 mm., and dilated at their lower ends to form thin-walled tubes 2 mm. in diameter, which are fused with the Wolffian ducts for a length of 6·5 mm. These latter

ducts are of equal size on the two sides in spite of the difference between the two testes, and present glandular enlargements at their lower ends corresponding to vesiculæ seminales.

Fig. 13 represents a transverse section through the lower ends of the Wolffian and Müllerian ducts of the left side, at the part where they are fused together externally. The figure shows clearly that the vesicula seminalis, *v.s.*, which is a branched tubular structure, is really an outgrowth of the Wolffian duct *w* and has no connection whatever with the Müllerian duct *m*. In the normal male frog the Müllerian duct is so slender that it is difficult to determine with certainty the relation between it and the vesicula seminalis, so that I have thought it well to examine the point in frog C, where the Müllerian duct is of considerable size. For this purpose the parts in question were cut into a series of transverse sections, one of which is drawn in fig. 13.

The vesicula seminalis commences some little distance above the point at which the two ducts come in contact with one another. It clearly arises as a series of branched diverticula of the Wolffian duct, lined by a layer of closely-packed columnar non-ciliated cells identical with those of the Wolffian duct itself.

The Müllerian duct is quite distinct along its whole length, and has no communication whatever with the vesicula seminalis. Furthermore, it is lined by an epithelium the cells of which are considerably larger than those of the Wolffian duct and vesicula seminalis, from which they differ also in being ciliated. A careful comparison of this series of sections with a similar series through the corresponding parts in a normal male frog, leaves no doubt that the vesicula seminalis is really developed from the Wolffian and not the Müllerian duct.

Frog D.—Of this specimen the genito-urinary organs, the only parts that have come into my hands, are represented twice the natural size in fig. 4; while figs. 5 and 6 represent lateral and dorsal views of the testis.

The ovary (fig. 4, *o*), which is present on the left side only, has a total length of 17 mm., with a width of about 6 mm., and thickness of 2.3 mm. It is divided by a strongly-marked transverse

constriction into two lobes, whereof the anterior and smaller is subdivided by a less pronounced constriction into two, and the posterior into four minor lobes. The whole ovary is of a deep brown, almost black, colour, and has its surface distinctly mapped out into polygonal areas. At certain places there are very evident ova, which are of a paler colour than the ovary itself, and attain a diameter of .8 mm. The fat body is small, and attached to the inner border of the ovary some 4 or 5 mm. behind its anterior end.

The testis which replaces the ovary on the right side is of the shape shown in figs. 4, 5, and 6. It measures 15 mm. in length by 8.5 mm. in width, and 6 mm. in thickness. It is marked on its ventral surface by a very deep transverse groove, which almost divides it into two parts, of which the upper or anterior is about half the size of the posterior. This groove, which is deepest along the inner border of the testis, is almost exactly opposite the deepest constriction of the ovary noticed above. On the dorsal surface of the testis, at its anterior end, is a deeply-pigmented lobe (figs. 5 and 6, *o.t.*), which has the appearance of being the real upper end bent back along the dorsal surface. From this lobe the pigment is continued down the outer side of the testis as a broad stripe, nearly 3 mm. wide, and with sharply-defined margins. The rest of the testis is of the usual colour, and the blood-vessels and vasa efferentia are normal. The fat body is unusually small, and is attached, not to the apex of the testis, but to its dorsal surface at the junction of the pigmented reflected lobe, *o.t.*, and the main body of the testis.

The ducts (fig. 4) have the normal female arrangement. The Wolffian ducts or ureters have no dilatations at their lower ends, and open independently and separately into the cloaca. Of the Müllerian ducts, the lower thin-walled and pigmented uterine dilatations are alone present in the specimen as received by me; these agree in size and in other respects with those of the normal female frog. I learn further from Professor Haddon that the upper parts of the ducts were also of the normal female pattern.

The very close correspondence between the ovary and testis in this specimen is worthy of note. They are placed exactly

opposite one another, and the arrangement of the blood-vessels is identical on the two sides. The pigmentation and the grooving of the surface of the testis are points of approach towards the condition of the ovary; while, on the other hand, the ovary is connected with the left kidney by two or three thin-walled tubules, which manifestly correspond to the vasa efferentia of the right side.

II.—*Histology.*

Frog B.—In dealing with the microscopic peculiarities of the parts described above, it will be convenient to begin with the consideration of frog B., as this presents with especial clearness the points to which I wish to direct attention.

The testes, which, with the other parts represented in fig. 2, had been preserved for more than a year in about 90 per cent. alcohol, were removed, stained with borax carmine, and cut into series of transverse sections, the right testis being cut from end to end, while of the left one the anterior half only was examined.

Fig. 9 represents a portion, about a fourth, of a transverse section through the middle of the right testis, magnified forty diameters; while fig. 8 is a small portion, drawn on a rather larger scale, of a section through the upper part of the left testis, the section passing through one of the prominent swellings already noticed (figs 2 and 3, *o'*). In fig. 9 it is seen that the greater part of the testis has the normal structure, being made up of a number of seminal tubes, with an average diameter of .3 mm., bound together by connective tissue supporting blood-vessels, &c., and lined by the spermatospores or seminal cells, the greater number of which in the specimens figured have given rise to groups of spermatozoa now almost ripe.

Wedged in between the seminal tubes, and apparently replacing them, there occur at intervals bodies which closely resemble ova in appearance, and which I believe, for reasons stated below, to be in reality ova. Of these, four are shown in fig. 9, *o*, and one more highly magnified in fig. 8.

These "ova" are not confined to one part, but are irregularly scattered throughout the whole of the right testis, every single section of the series into which the testis was cut presenting at

least one, and the majority having as many as five or six. At the upper part of the testis they are situated close to the surface, and the largest ones give rise to the protuberances noticed above, and seen in figs. 2 and 3. In the greater part of the testis they occur, however, both close to the surface and deeply imbedded in its substance (fig. 9).

They vary in size from .27 by .16 mm. up to .55 by .41 mm., *i.e.*, they may slightly exceed the seminal tubes in diameter, though they are as a rule of about the same size, or slightly smaller than these. At the upper part of the testis they are associated with polygonal pigment cells (fig. 8, *p*), which, however, are entirely outside them, and confined to the connective tissue stroma of the testis. The pigment cells only occur close to the surface, and the great majority of "ova" are entirely free from them.

Each "ovum" (figs. 8 and 9, *o'*) consists of a granular matrix which stains very readily, and presents under high power a very manifest reticular appearance. The "ovum" is enclosed in a delicate connective-tissue follicle, which as a rule it does not completely fill, giving the impression of having shrunk away from the follicle wall, with which it remains connected by a delicate reticular network continuous with that of the matrix. The matrix varies a good deal in different cases; it may be very compact and granular, in which case the ovum usually completely fills the follicle; or it may be very obviously reticular, or even largely vacuolated, and occupy but a small part of the follicle.

Within the matrix, and usually excentrically situated, is an oval cavity, measuring up to .25 mm. in diameter, in which lies the "nucleus" (figs. 8 and 9, *n*). This rarely fills the cavity in which it lies; it is granular, stains more darkly than the matrix, and contains a large number of deeply staining spherical "nucleoli," of which there may be as many as 200 visible in a single section, the largest attaining a diameter of .004 mm. In some cases there is, as shown in fig. 8, a marked tendency for the protoplasm of the "nucleus" to collect around the "nucleoli." This is generally most evident at the surface of the "nucleus," which may be distinctly marked off into areas corresponding to the nucleoli. It is also best seen in those cases in which the "nucleus" completely fills the cavity of the matrix.

These bodies clearly represent no stage in the normal development of the male genital elements. On the other hand, they do agree very closely with certain conditions of the female genital elements, and it is for this reason that I have spoken of them as "ova."

The resemblance is indeed a very close one. Fig. 11 represents part of a transverse section through the ovary of a normal female frog at the end of the first year. The ovary of the frog is as is well known a hollow organ,¹ whose wall consists of (1) an outer layer of squamous epithelium; (2) a thin layer of connective tissue, thickened at places to support the blood-vessels (fig. 11, *b*); (3) an inner lining of squamous epithelium.

At intervals the surface epithelium becomes thickened, giving rise to a deeper layer of spherical or polygonal cells (fig. 11, *ge*), from which the ova are derived. Certain of the cells of this germinal epithelium increase in size and form ova, round which the remainder form follicular investments. The ova, by their further growth, project inwards into the cavity of the ovary (fig. 11), each ovum having a double epithelial investment, an outer one (fig. 11, *r*), formed by the squamous epithelium lining the cavity of the ovary, and an inner one derived from the follicular cells of the germinal epithelium (fig. 11, *s*), and consisting of a single layer of slightly flattened polygonal cells with large granular nuclei up to .009 mm. in diameter, very scanty protoplasm, and very indistinct outlines.

This inner layer of follicular epithelium is very intimately connected with the protoplasm of the ovum; the latter, often shrinks away from the follicle, possibly owing to the action of the hardening reagents, but in such cases a narrow zone is always left adherent to the follicular cells.

At the edge of the follicle, close to the stalk of attachment of the ovum, the connective-tissue layer of the ovary can readily be recognised between the two epithelial layers, but it cannot as a rule be traced as a distinct layer all round the follicle.

The nucleus of the ovum is at this period very imperfectly bounded, the line of separation between it and the protoplasm being very irregular, and often indistinct. The nucleoli are

¹ My observations on the frog's ovary are in close agreement with the excellent account given by Waldeyer, *Eierstock und Ei*, pp. 72 seq.

very numerous, as many as 150 or 200 being sometimes visible in a single section. They vary a good deal in size, and are more abundant toward the periphery of the nucleus. In many cases the protoplasm of the nucleus exhibits a marked tendency to collect around the nucleoli (fig. 11). In the later stages of development during the second year the ova increase greatly in size through the accumulation within them of yolk plates; pigment appears first in the follicles, and then invades the ova themselves, and the nuclei become vesicular with sharply defined walls.

The correspondence between the ovarian ova of the female frog at the end of the first year, and the bodies described in the testis of frog B, is clearly a very close one, as is evident from the description given above, or from a comparison of figs. 8, 9, and 11. In actual size there is a fairly close agreement, and the condition of the protoplasm and especially of the nuclei and nucleoli is practically identical in the two cases, so that there can I think be no doubt that the bodies found in the testis of frog B are true though immature ova. This conclusion is rendered still more evident by the consideration that while agreeing closely with ova, the bodies *o'* in figs. 8 and 9 differ absolutely as regards size and condition of nuclei from any other structure found in the body of the frog. If the ovary of a normal female frog be examined very shortly after the time of spawning, ova will be found which agree still more closely with those of frog B. These are of smaller size than usual, and exhibit a distinct tendency to disintegration; the protoplasm shrinks, especially at its peripheral part, and becomes much vacuolated, while the nuclei also diminish in size so as no longer to fill the spaces in which they lie, the general condition being identical with that shown in figs. 8 and 9.

The genital glands of frog B must therefore be regarded as hermaphrodite glands in which the male element preponderates strongly, the spermatozoa being in all respects normal; while the female element is represented by a large number of immature and in many cases apparently degenerating ova, which occur irregularly scattered throughout the substance of both glands.

Concerning the projection on the top of the right genital gland (fig. 3, *a*), sections show that it consists in part of a normal

testicular structure containing ripe spermatozoa, and in part of ova in a state of extreme degeneration; the best marked cases consisting of pigmented follicles, reaching a diameter of nearly 1 mm., and containing granular, pigmented, and in places fatty debris. The connective tissue is considerably increased in quantity, and the surface projections seen in fig. 3 are due to local accumulations of this connective tissue, and not to either seminal tubes or ova.

Frogs A. and C.—Of these specimens sections and other preparations were made of the testis, which however show the normal testicular structure throughout, with no trace of ova.

Frog D.—The Right Genital Gland.—The greater part of the right genital gland (fig. 6, *t*) has the normal testicular structure, and presents no features calling for special notice.

The pigment band along the outer edge extends inwards about a quarter of the way through the substance of the testis. It consists of masses of polygonal nucleated pigment cells, which follow the lines of the intertubular connective tissue, and whose development is accompanied by sclerotic increase or hyperplasia of this tissue. The pigment is in most cases entirely outside the seminal tubes, which, by the increase of the intertubular connective tissue, become crushed together and obliterated; it is only when the tubes are in the last stages of atrophy that pigment can be seen within them.

The pigmented dorsal lobe (figs. 5 and 6, *o.t.*) has an altogether different structure. As shown in fig. 12, which represents part of a section through its widest portion, this lobe is ovarian rather than testicular in nature. If this figure be compared with fig. 11, it will be seen that the lobe in question agrees in all essential respects with a true ovary, from which it differs mainly in the great increase in thickness of the connective tissue layer, and in the great abundance of pigment cells.

The lobe is a hollow body, whose wall, though varying at different places, has an average thickness of not less than 4 mm. The greater part of the thickness of the wall consists of fibrous connective tissue, in which are imbedded an immense number of polygonal pigment cells; it is traversed by numerous blood-

vessels with greatly thickened walls. The outer surface of the lobe is nearly smooth, but on the inner surface the thickened wall forms numerous rounded masses projecting into the central cavity. Attached to the inner surface of the wall, and hanging down into the cavity of the lobe, are numerous ova, closely resembling those of the normal female ovary drawn in fig. 11. In some cases these ova reach, and are attached to, the surface epithelium of the lobe, but the great majority are separated from the surface by a considerable thickness of the pigmented connective tissue.

The ova are of considerable size, the largest having a diameter of .75 mm. Each is enclosed in a follicle, having the structure described above in the case of the true ovarian ovum, *i.e.*, consisting of inner and outer epithelial layers between which is a thin connective tissue layer. This latter can be more readily traced than in the normal ovum, owing to its participating to a slight extent in the general hyperplasia to which the connective tissue is subjected.

The protoplasm of the ova consists of an outer reticular portion which stains feebly, and is closely connected with the inner layer of follicular epithelium, and an inner more compact and darkly staining part usually situated near the pole of the ovum furthest from the stalk of attachment. In this latter portion is the nucleus, which usually has a very irregular but sharply-defined outline, and presents in its superficial portion a large number of spherical nucleoli, round which the protoplasm of the nucleus exhibits the same tendency to collect noticed already in the case of the early ovarian ova.

Some of these ova appear to be in thoroughly healthy condition, but the majority are in various stages of degeneration, the protoplasm having shrunk from the follicle wall, the nuclei being of small size, and the follicle being in some cases invaded by pigment cells.

One instance, shown at the left hand side of fig. 12, is of some interest. The follicle wall is thicker than usual, and the protoplasm of the ovum, which has shrunk slightly from the follicle, contains a large number of nuclei scattered throughout its substance, the nuclei being granular and in some cases slightly pigmented. This appears to represent a stage in the ultimate

degeneration of the ova, as other cases occur in which the pigmentation is more evident, and the whole protoplasm of the ovum broken up into cells, more or less strongly pigmented.

The ova of the pigmented lobe of frog D are of interest, because, while on the one hand there can be no doubt, from their relations to the wall of the lobe, from the characters of the follicles in which they are enclosed, and from their histological structure, that they are true ova; they are, on the other hand, in some respects, such as the shrinkage of the protoplasm from the follicle wall, and its reticular or vacuolated appearance, intermediate between the normal ovarian ova shown in fig. 11, and the more highly modified ones found in the ovotestes of frog B (figs. 8 and 9), serving, in fact, to completely remove any doubt that might still be felt as to the real nature of these latter.

The Left Genital Gland.—This, as already noticed (fig. 4, o), has externally the appearance of a normal ovary more strongly pigmented than usual. Examined microscopically, it is found to agree in all respects with the pigmented lobe of the right side described above, and drawn in fig. 12. So close is the resemblance that the above figure would do equally well for the genital organ of either right or left side, and any detailed description of the left gland is unnecessary.

The points in which it differs from the normal ovary are the fibrous hyperplasia and pigmentation of the connective tissue coat of the outer wall, with accompanying increase in the number of the blood-vessels and in the thickness of their walls. Though the larger ova may be separated from the surface epithelium of the ovary by a considerable thickness of the pigmented connective tissue, yet they appear to take their origin in all cases at the surface; and the patches of germinal epithelium (fig. 12 *ge*), from which they start, are in all respects similar to those of the normal ovary.

Frog D appears then to be really hermaphrodite, but it is worthy of note, that while the male portion of the essential glands is absolutely normal in structure throughout, the female portion, though more bulky, forming the whole of the left gland and part of the right one as well, is not normal in any part, the majority of the ova showing more or less well-marked signs of

degeneration, and the whole structure exhibiting very obvious sclerotic induration, which must be regarded as pathological. The ducts, as already noticed, present the typical female form and arrangement.

GENERAL CONSIDERATIONS.

The Genital Glands of the Toad.—It has long been known that in various species of toads, the males, at any rate while young, have attached to the top of each testis an organ closely similar to the ovary of the female.

This structure has been described by many writers, notably by Rathke,¹ Jacobson,² Bidder,³ Von Wittich,⁴ Leydig,⁵ Spengel,⁶ and La Valette St George.⁷ Concerning the anatomical relations of the parts concerned all writers agree, though they differ much as regards the interpretation to be placed on the appearances recorded.

The general relations are shown in fig. 7, which represents the urino-genital organs of a young male specimen of *Bufo vulgaris* (Flem.) dissected for the purpose. The total length of head and trunk in this case is 46 mm. The testes (fig. 7, *t*) are a pair of compact oval yellowish bodies, measuring 6 by 2·8 mm., and attached in the normal manner to the ventral surface of the kidneys, rather below the middle of their length. On the top of each testis is a small reddish-yellow body (fig. 7, *a*) nearly equal in size to the testis itself, and of rather darker colour. This is the "rudimentary ovary" of Jacobson and Von Wittich, which

¹ Rathke, *Beiträge zur Geschichte der Thierwelt*, iii. Abtheilung, p. 29, 1825.

² Jacobson, *Det Kongelige Danske Videnskabernes Selskabs Naturvidenskabelige og Mathematiske Afhandlingar*. Tredie Deel, p. 42, 1828.

³ Bidder, *Vergleichend anatomische und histologische Untersuchungen über die männlichen Geschlechts und Harnwerkzeuge der nachten Amphibien*, p. 27 seq. Dorpat, 1846.

⁴ Von Wittich, "Beiträge zur morphologischen und histologischen Entwicklung der Harn und Geschlechtswerkzeuge der nachten Amphibien," *Zeitschrift für Wissenschaftliche Zoologie*, bd. iv. pp. 125–167, 1853.

⁵ Leydig, *Anatomisch-Histologische Untersuchungen über Fische und Reptilien*—Berlin, 1853, p. 72.

⁶ Spengel, "Das Urogenitalsystem der Amphibien," *Arbeiten aus dem Zoologisch-Zootomischen Institut in Würzburg*, bd. iii., 1876, pp. 100–102.

⁷ La Valette St George, "Ueber die Genese der Samenkörper," *Archiv für Mikroskopische Anatomie*, bd. xii., 1876, p. 808.

may perhaps better be referred to as "Bidder's organ," the name given it by Spengel.¹ It has in the specimen figured a maximum length of 4.5 mm., with a width of 2.9 mm. and thickness of 2 mm. Its dorsal surface is slightly concave, fitting like a cap on to the top of the testis; with which however it is connected, as with the large fat body, by connective tissue only. The surface has a warty appearance owing to a number of small hemispherical protuberances.

The ureter runs along the outer border of the kidney, and is joined just below the lower edge of the kidney by the Müllerian duct (fig. 7, *m*), an almost straight and very slender tube, which opens in front into the coelom in the normal position close to the root of the lung. The combined Müllerian and Wolffian ducts run down to the cloaca without forming any dilatation.

When examined histologically, Bidder's organ presents the appearance shown in fig. 10, which represents a transverse section taken about the middle of its length. The greater part of the organ consists of a densely packed mass of bodies (fig. 10, *o*), which agree closely in structure with true ova, though they do not attain the size of the ripe ovarian ova. In the centre of the organ is a cavity, which however is of small size, and is traversed by trabeculæ of connective tissue accompanied by blood-vessels.

The ova, as shown in the figure, vary considerably in shape, size, and structure. They are usually, from mutual pressure, polygonal, except at the surface where they form rounded projections, but at places they become much distorted in shape, forming wedge-shaped masses filling up the interspaces between the larger and more typical ova. Their average diameter is about .27 mm., but they may measure .35 mm. or more.

Each ovum is contained in a delicate connective-tissue follicle, which separates it from its neighbours; in fact, the whole organ might be described as consisting of a network of fine connective tissue trabeculæ, the meshes of which are occupied by the ova. Lining each follicle is a layer of epithelial cells with rather large nuclei, which latter become very conspicuous when, as happens in many cases, the protoplasm of the ovum has shrunk away from the follicle wall.

¹ Spengel, *loc. cit.*, p. 100.

The ovum may completely fill the follicle, but more usually the protoplasm, which has a finely reticulated appearance under high powers, has shrunk away from the wall either at one or more places, or else the whole way round; in extreme cases the follicle may be almost empty, the protoplasm forming an irregular and loosely reticulated mass occupying its centre only. The nucleus varies much in appearance; it may be spherical or oval in shape, with sharply-defined outline, and a number of darkly staining nucleoli arranged near its periphery, or it may present a more or less shrunken and degenerate appearance, being of irregular shape and occupying only a small part of the cavity of the protoplasm in which it lies. In many instances the tendency of the protoplasm to collect around the nucleoli is very marked, taking place in exactly the same manner as in the case of the true ovarian ova described above.

The true nature of Bidder's organ in the toad has been the subject of much dispute. Rathke¹ appears to have overlooked the existence of the true testis altogether, and consequently describes Bidder's organ as the testis. Jacobson² refers to it as a rudimentary ovary which is frequently but not invariably present in toads. Bidder,³ who makes special mention of the close resemblance between the characteristic bodies of Bidder's organ and true ova, nevertheless maintains that Bidder's organ is really a part of the essential male genital apparatus. This view was completely refuted by Von Wittich,⁴ who showed that there is no communication whatever between Bidder's organ and the testis, and that the former has no ducts of any kind, while the true testis is of the normal structure and connected by vasa efferentia with the kidney tubules. Von Wittich, who has investigated the matter in great detail, has further shown that Bidder's organ is formed from the anterior part of the genital ridge, of which the hinder portion becomes the testis; he finds also that Bidder's organ is always largest during the first year, and that while in some cases, as *Bufo cinereus*, it persists throughout life, though in a degenerate and pigmented condition, in other cases, of which *Bufo variabilis* and *Bufo calamita* are instances, it begins to atrophy about the third year, and ulti-

¹ Rathke, *op. cit.*, p. 29.

³ Bidder, *op. cit.*, p. 28.

² Jacobson, *loc. cit.*, p. 42.

⁴ Von Wittich, *op. cit.*, p. 160 *seq.*

mately disappears completely. He regards Bidder's organ as being really a rudimentary ovary.

Leydig takes a similar view, and says of Bidder's organ:—
 “Und selbst unter dem Mikroskop behaupten diese Körner und Höcker ihre Ei-ähnlichkeit aufs glänzendste und ich gestehe, dass ich sie nicht von Eierstockseirn desselben Thieres unterscheiden kann; es sind Kapseln oder Blasen gefüllt mit Fettkörnchen und im Innern liegt ein zweites heller Bläschen mit zahlreichen klaren Flecken, Keimflecken durchaus ähnlich.”¹

In this he is followed by La Valette St George, who says:—
 “Dass es wirkliche, wenn auch nie zur Reife kommende Eier sind welche jener Organ enthält, lässt der erste Blick erkennen. Wollte man ein Demonstrations Präparat für die Eierstockseier der Kröte gewinnen, so würde man es eher dem männlichen als dem weiblichen Thiere entnehmen, weil dort ein solches ein leichter zu gewinnendes und instructiveres Bild darböte.”²

Spengel,³ on the other hand, disputes the ovarian character of Bidder's organ for three chief reasons:—

1. The anatomical differences between Bidder's organ and the true ovary. These consist in the small size (absence, according to Spengel) of the central cavity of the organ; the arrangement of the egg-like cells in several layers instead of a single one, and the absence of pigment in the cells themselves.

2. The fact that a structure identical with Bidder's organ is present in the female toad, occupying a position between the fat body and the ovary precisely similar to that held by Bidder's organ in the male.

3. The condition of the generative organs in a hermaphrodite specimen of *Bufo cinereus*, in which there was on each side a testis of normal structure, though somewhat shorter than usual; and in front of this a true ovary, between which and the fat body was a Bidder's organ of the usual structure.

The actual nature and import of Bidder's organ Spengel does not attempt to decide definitely, though he expresses an opinion that Bidder's view of it, as a part of the testis which has stopped at an early developmental stage, and acts as an accessory male organ, may prove to be correct.

¹ Leydig, *op. cit.*, p. 71.

² La Valette St George, *loc. cit.*, p. 808.

³ Spengel, *loc. cit.*, pp. 100-102.

Concerning these various views, it may be noted that Rathke was undoubtedly wrong in his determination of Bidder's organ as a testis; for, when examined microscopically (fig. 10), it presents no trace whatever of spermatozoa either mature or immature. Of the other writers, Jacobson, Leydig, and La Valette St George maintain the ovarian character of the organ, which is denied by Bidder and Spengel.

It appears to me that the bodies *o'* in fig. 10, making up the bulk of Bidder's organ, must be regarded as ova. The organ itself is proved by Von Wittich to be merely the anterior portion of the genital ridge of the young toad;¹ and, concerning the bodies themselves, it must be noted, that while they correspond to no stage whatever in the development of the spermatozoa either of the toad or of allied animals, while in fact they resemble no other structures in any part of the body, they do agree closely with ova as regards both structure and relations, and are identical with certain conditions of partial degeneration of ova met with under special circumstances.

Thus the layer of follicular epithelium immediately investing the "ova" of Bidder's organ (fig. 10, *s*) clearly corresponds to that seen in the ovotestis of frog B (fig. 8, *s*), while this again is identical with that of the ova in the ovotestis of frog D (fig. 12), and of the true ovarian ova (fig. 11).

Again, the varying condition of the protoplasm of the "ova," and also of the nuclei, and more especially the tendency of the protoplasm of the nuclei to collect around the nucleoli—all these are characteristic alike of Bidder's organ, of the ovotestes of frogs B and D, and of certain states of the true ovarian ova, especially just after the period of oviposition.

I regard it therefore as established, that the bodies *o'* in fig. 10 really are ova, which have for some reason been arrested in their development—both Von Wittich and Spengel have shown that they never attain maturity—and which are in varying conditions of degeneration and atrophy. Regarding the differences insisted on by Spengel between Bidder's organ and an ovary, I would point out that there really is a central cavity in the former, although it is but a small one.

The arrangement of the "ova" in several rows, instead of, as

¹ Von Wittich, *loc. cit.*, p. 158.

in the normal ovary, in a single one, I do not regard as an objection of much weight, especially when we consider the condition in the frogs B and D. There can be no doubt that the body *s* in fig 8 corresponds to one of the ova of figs. 11 or 12; and fig. 9 shows us that identical bodies occur imbedded in all parts of the ovotestis of frog B. The resemblance between figs. 9 and 10 is a very instructive one. In both cases the ova are arranged in more than a single layer, and in both cases each ovum has its own connective-tissue follicle.

Concerning the absence of pigment from the ova of Bidder's organ, I will merely note—firstly, that at the stage of development at which these ova are arrested there is no pigment in the true ovarian ova; and, secondly, that in the case of corresponding structures in the frog, pigment may, as we have seen in fig. 12, invade not merely the connective tissue but the ova themselves.

CONCLUSION.

As to the real meaning and explanation of these curious conditions of the genital organs in Amphibia, I think that further evidence is necessary before we can decide definitely. I would, however, submit the following considerations, which may throw some light on the subject:—

We learn from Von Wittich's descriptions¹ that the reproductive organs both of Anurous and Urodelous Amphibia arise about the time of appearance of the limbs as a pair of longitudinal ridges, consisting of closely-packed moderately large nucleated cells with granular contents. Each ridge is very early divided by a slight transverse constriction into two parts—an anterior wider and rounder one and a posterior more slender one. Of these the anterior part becomes the fat body of the adult, and the posterior part the true genital gland. The various stages of formation of the fat body are carefully described by Von Wittich, whose account must I think be accepted. According to him, fat globules appear within the cells, and rapidly increase in number, converting the cells into ordinary fat cells. The further increase in number of the cells gives rise to the well-known finger-like processes of the adult fat body.

¹ Von Wittich, *loc. cit.*, p. 147 *seq.*

It appears, therefore, that in both Anura and Urodela the anterior end of the genital gland undergoes retrograde development in the form of fatty degeneration at a very early period, while the gland itself is still in a sexually indifferent condition. This circumstance throws light on the condition of the genital organs in frog C, in which, as described above, the fat body is of great size on both sides, and the right testis represented by a small oval mass only 2.5 mm. long, and consisting almost entirely of fat. In this case the process of fatty degeneration appears to have extended further than usual, and to have involved the whole length of the genital ridge on the right side, instead of, as usual, the anterior end only.

A still more striking case has very recently come into my hands; viz., a frog, which may be called E, in which the fat bodies are of very great size on both sides, the base of attachment to the peritoneum in front of the kidney being 12 mm. in length, while the reproductive organs are represented by a pair of small oval masses of fat only 2 mm. long. The Müllerian ducts are convoluted, and of about the size they attain in the normal female frog at the end of the first year. The Wolffian ducts have distinct dilatations at their lower ends clearly corresponding to vesiculæ seminales. As such dilatations are never met with in the female, while convoluted Müllerian ducts may occur in the male as we have seen above, frog E is probably to be viewed as an aborted male.

The tendency of the anterior part of the genital ridge to undergo fatty degeneration is not confined to Amphibia. Brock¹ has shown that in certain Murænoid Teleosteans, such as *Myrus* and *Conger*, the anterior part of the testis normally undergoes fatty degeneration, sometimes as much as two-thirds of the entire organ being involved in the process, and the atrophied part becoming ultimately reduced to a connective-tissue network with empty meshes. In the ovaries also of *Myrus* and *Conger*, a large number of the genital cells abort and undergo fatty degeneration.

Concerning Bidder's organ in the toad, Von Wittich has shown²

¹ Brock, Untersuchungen über die Geschlechtsorgane einiger Murænoiden, *Mittheilungen aus der Zoologischen Station zu Neapel*, bd. ii., 1881, p. 438 *seq.*

² Von Wittich, *loc. cit.*, p. 158.

that it appears first as a slightly swollen part of the genital ridge immediately behind the fat body. This rapidly increases in size, and in both sexes at the end of the first year considerably surpasses in size the true genital gland behind it. From this point it ceases to grow, and may either as we have seen retrograde and disappear, or may persist throughout life. Spengel has also described the development of Bidder's organ in the female toad, and his account agrees closely with that of Von Wittich. According to him,¹ Bidder's organ is simply the anterior end of the ovary, which from an early stage is much more compact than the hinder part, but consists of cells which agree in all essential respects with the ova of the hinder part of the ovary, differing merely in possessing a somewhat higher follicular epithelial layer. While, however, the ova of the true ovary are increasing in size and acquiring yolk plates and pigment, the ova of Bidder's organ remain for a time in their primitive condition, and then gradually retrograde.

So far then as the female toad is concerned, the formation of Bidder's organ may, I think, be regarded as due to a further extension backwards of that tendency to degeneration and atrophy which has caused the conversion of the most anterior part of the genital ridge into the fat body, a tendency which we have seen to be well marked in Amphibia, and to manifest itself occasionally in Teleostei as well. This further tendency appears to have manifested itself at a much later date than the earlier one, for while the fat body occurs in both Urodela and Anura, Bidder's organ is confined to the more highly specialised group—the Anura. The great interval that must have elapsed between the successive manifestations of the tendency to abortion may perhaps in part explain the different course that tendency has taken in the two cases. It is also possible that the tendency to shortening of the genital organs in Anura may be associated with the general tendency to shortening and concentration that distinguishes Anura from Urodela, manifested in the absorption of the tail, the actual shortening of the alimentary canal during development, and the tendency to concentration shown by the kidneys and their ducts.

While however this explanation may account for the occur-

¹ Spengel, *loc. cit.*, pp. 97–98.

rence of Bidder's organ in the female toad, something further is necessary to account for its presence in the male as well. So far as both structure and development go the organ is identical in the two sexes, Von Wittich's account of its development in the male agreeing exactly with Spengel's of the female. Bidder's organ in the male toad must therefore be regarded as a *rudimentary ovary*.

This fact has been employed by Von Wittich¹ and Waldeyer² as an argument in favour of the view that vertebrates are to be regarded as primitively hermaphrodite. I do not think that this view, which has been maintained by Haeckel³ and others, derives any real support from the condition of the genital organs in Anura. In the first place, it must be noticed that, according to Von Wittich's account, Bidder's organ appears in the toad while the genital ridge is still in a sexually indifferent condition, and it is not till after its separation that the posterior part of the ridge becomes ovary or testis. Furthermore, it must be noted that all the apparently hermaphrodite conditions described as occurring constantly or occasionally in Anura are cases in which the male organs have taken on more or less completely the female type of structure. In no case do we find any tendency to the development of male organs in an undoubted female. This is illustrated admirably by Bidder's organ, which in both sexes has the structure of a degenerate ovary, while the exceptional cases described in the earlier part of this paper as occurring in frogs, must, as already pointed out, be regarded as examples of males in which the genital organs, essential and accessory, have assumed to a certain extent the characters of the female organs. Were a condition of hermaphroditism really primitive, it would be reasonable to expect that cases would occur of undoubted females assuming the characters of males; but this, so far as I know, does not happen.

Why these aborted parts, such as Bidder's organ in the toad, or the upper parts of the testes of frogs B and D described above, should tend towards the female rather than the male type, is a point that I fear we are not yet in a position to determine. The explanation may however be that the female organ—the

¹ V. Wittich, *loc. cit.*, p. 163-6.

² Waldeyer, *Eierstock und Ei*, 1870, pp. 152-3.

³ Haeckel, *Anthropogenie*.

ovary—is, on the whole, of a simpler and more primitive type than the male organ or testis: simpler as regards the actual details of development; more primitive because conjugation must undoubtedly have first occurred between two similar cells, and of the ovum and spermatozoon the latter is most certainly the more highly differentiated. Degeneration of the male genital gland may then be regarded as taking the form of reversion to the more primitive ovarian type.

It would be foreign to the objects of the present paper to discuss in detail the general question whether a condition of hermaphroditism is or is not primitive among vertebrates; and I would merely point out in conclusion, firstly, that the answer to the question must be obtained not from vertebrates but from their invertebrate ancestors; and secondly, that much confusion appears to have arisen from a failure to distinguish accurately between the primitively indifferent sexual condition which is undoubtedly common to all vertebrates, and a primitively hermaphrodite condition of which, to my mind, no satisfactory evidence has yet been brought forward.

DESCRIPTION OF PLATES VI. AND VII.

All the figures were drawn directly from the objects themselves, and in the case of figs. 8–13 from single sections. The numbers attached indicate, in diameters, the magnifying power employed.

Alphabetical List of References.

<i>a.</i> Bidder's organ.	<i>o.</i> Ovary,
<i>b.</i> Blood-vessel.	<i>o'.</i> Ovum.
<i>c.</i> Cloaca.	<i>ot.</i> Ovarian lobe of testis.
<i>d.</i> Œsophagus.	<i>p.</i> Pigment.
<i>e.</i> Bladder.	<i>r.</i> Outer layer of follicular epithelium of ovum.
<i>f.</i> Fat body.	<i>s.</i> Nuclei of inner layer of follicular epithelium.
<i>g.</i> Aortic arch.	<i>t.</i> Testis.
<i>ge.</i> Germinal epithelium.	<i>t'.</i> Sperm cell.
<i>h.</i> Heart.	<i>t''.</i> Spermatozoa.
<i>i.</i> Large intestine.	<i>ts.</i> Seminal tube.
<i>i'.</i> Small intestine.	<i>v.</i> Vasa efferentia.
<i>k.</i> Kidney.	<i>vs.</i> Vesicula seminalis.
<i>l.</i> Lung.	<i>w.</i> Wolffian duct.
<i>m.</i> Müllerian duct.	<i>x.</i> Vena cava inferior.
<i>m'.</i> Uterine dilatation of Müllerian duct.	<i>y.</i> Renal vein.
<i>n.</i> Nucleus.	
<i>n'.</i> Nucleolus.	

Fig. 1. Frog A, dissected so as to show the urino-genital organs from the ventral surface. The alimentary canal has been removed, with the exception of the oesophagus and large intestine. The right testis has been removed, and the left one turned over to the right side, so as to show the vasa efferentia. $\times 1$.

Fig. 2. Frog B, dissected so as to show the urino-genital organs from the ventral surface. $\times 1$

Fig. 3. The right testis of frog B, seen from the ventral surface, the fat body being slightly displaced so as to show the anterior lobe, *a*, of the testis. $\times 3$.

Fig. 4. The urino-genital organs of frog D removed from the body, and seen from the ventral surface. The lower ends alone of the Müllerian ducts are represented. $\times 2$.

Fig. 5. The right genital gland or testis of frog D seen from the outer surface. $\times 2$.

Fig. 6. The right genital gland or testis of frog D seen from the dorsal surface, showing the ovarian lobe, *ot*. $\times 2$.

Fig. 7. A young male toad—*Bufo vulgaris*—dissected so as to show the urino-genital organs from the ventral surface. $\times 2$.

Fig. 8. Part of a transverse section through the upper part of the left testis of frog B. $\times 55$.

Fig. 9. Part of a transverse section through the middle of the right testis of frog B, showing ova wedged in between the seminal tubules. $\times 40$.

Fig. 10. Part of a transverse section through the middle of Bidder's organ in the young male toad drawn in fig. 7. Shows ova in various stages of degeneration. $\times 55$.

Fig. 11. Part of a transverse section through the ovary of a normal female frog—*Rana temporaria*—at the end of the first year, showing developing ova. $\times 40$.

Fig. 12. Part of a transverse section through the widest part of the dorsal ovarian lobe, fig. 6 *ot*, of frog D, showing the central cavity, thick pigmented walls, and ova. $\times 40$.

Fig. 13. Transverse section through the Wolffian and Müllerian ducts of frog C, showing the origin of the vesicula seminalis as branched outgrowths from the Wolffian duct.

THE UREA ELIMINATION UNDER THE USE OF
POTASSIUM FLUORIDE IN HEALTH. By L. A.
WADDELL, M.B., *Resident Physician, Medical College
Hospital, Calcutta.*

THE following observations were made on three healthy individuals, who, having constituted themselves into a "proving" committee, were testing on their own person the action of the alkaline fluorides.

The provers were Assistant-Surgeons G. Sarkara and N. C. Basu, M.B., of the Medical College Hospital, Calcutta, and the writer. The following is a brief statement of their physical condition :—

Name.	Age.	Body-weight.	Temperament.
Sarkara, . . .	26	118 lbs	Nervous.
Basu, . . .	25	162 „	Lymphatic.
Waddell, . . .	28	148 „	Sanguine.

The drug was given in a simple form, without accessories, and the quantity taken in the twenty-four hours is shown in column 2 of table I.

The process employed for the determination of the urea was Davy's hypobromic method, as modified by Russell and West. The amount as registered by the instrument was noted, without any correction being made for temperature; but, as Russell and West graduated their apparatus for a temperature of 65° Fahr.,¹ and the temperature at which the present series of observations was taken averaged 70° Fahr., the urea will thus be over-estimated to the extent of 1·38 grains in every 100 grains. But even although this small difference be not allowed for, as it is a constant quantity it will in no way invalidate the comparative significance of the series of observations.

In estimating the amount of urea excreted in the urine it is

¹ *Journ. Chem. Soc.*, p. 749, 1874.

of course highly desirable to ascertain at the same time the amount of nitrogen which enters into the composition of the person's diet. But as, in the present case, this could not be readily determined with accuracy, the physiological urea excretion for several days was taken so as to arrive at a reliable mean. Parkes says¹ that an average of not less than six days will give the amount proper to the individual living on a non-regulated diet; but if the mode of life be kept very equable, the amount remains pretty constant from day to day. In the observations about to be referred to, the diet and mode of life were carefully regulated throughout, and all that might exercise a disturbing influence on the various functions of the body was studiously avoided, so as to ensure the normal excretion being estimated as correctly as possible, and thus afford a safe standard for comparison with the secretion under the fluorides.

It will be remembered that in a healthy adult male in England, taking regular exercise, Parkes estimated (by the volumetric method of Liebig) the mean amount of urea excreted in the twenty-four hours as being 371·5 grains. But most modern authorities put the average amount at a much higher estimate, viz., at about 30 grammes—the amount varying with the kind of food taken, the weight of the individual, sweating, &c. Taking the normal excretion as 1, a starch and sugar diet lessens the urea to 0·474 or more than one-half.² The temperature of the atmosphere also affects the amount of the secretion, independently of the loss by sweating, thus Kaupp³ states that an elevation of $2\frac{1}{2}^{\circ}$ Fahr. diminishes on an average the urea by 1·852 grains in the twenty-four hours. This latter circumstance, together with the more or less non-nitrogenous nature of their food, must be kept in view when considering the normal urea excretion of the natives of this country, of which, unfortunately, there are no reliable statistics yet published.

The results are given in the two accompanying tables. The physiological excretion during six days was determined, then all the conditions being kept as equal as possible, the medicine was administered, and the composition of the urine analysed during

¹ *On the Composition of the Urine*, p. 8.

² Lehmann, quoted by Parkes.

³ *Archiv. fur. Phys. Heilkunde*, 1855.

the subsequent days. As the differences fall beyond the limits of error, and no other cause of variation can be made out, they

TABLE I.

Showing Details of Daily Urinary Excretion (*own*) under the use of Potassium Fluoride. Diet mixed, but regulated.

Date.	Drug.	Quantity of Urine in previous 24 hours, in ounces.	Sp. Gravity of Mixed Urine.	Urea in whole quantity, in grains.	Atmospheric Conditions.			
					Temperature.		Humidity.	Rain-fall.
					Max.	Min.		
Feb. 16	None.	47	1019	304.73	82.1	53.3	30	None.
" 17	"	40	1021	306.25	82.4	56.3	48	"
" 18	"	38	1022	274.32	82.6	58.3	77	"
" 19	"	41	1019	295.90	82.6	60.3	50	"
" 20	"	33	1024	303.23	85.6	60.3	48	"
" 21	"	37	1023	301.75	89.5	66.7	51	"
" 22	3 grs.	38	1021	300.25	88.5	65.7	30	"
" 23	3 grs.	49	1019	349.00	86.6	60.3	25	"
" 24	6 grs.	58	1018	355.25	87.6	60.8	30	"
" 25	12 grs.	56	1018	367.50	83.6	59.8	78	1.43"
" 26	12 grs.	59	1017	335.56	82.6	59.8	80	None.
" 27	None.	63	1017	350.00	89.6	64.2	77	0.66"
" 28	"	50	1018	304.37	87.1	63.7	86	None.
Mar. 1	"	46	1018	271.85	80.6	68.7	83	"
" 2	"	41	1020	287.00	83.1	68.7	85	"

TABLE II.

Showing the Mean Daily Urinary Excretion under the Use of Fluoride of Potassium.

Prover.	Constituents.	Normal Excretion before taking Fluoride.	During taking of Fluoride.				After stopping Fluoride.			
			In first 2 days.		In next 3 days.		During first 2 days.		During next 2 days.	
				Increase over normal.		Increase over normal.		Increase over normal.		Difference from normal.
W.	Water, .	39.3 oz.	43.5	4.2	57.6	18.3	56.5	17.2	43.5	+ 4.2 oz.
	Urea, .	297 grs.	325	29	352	56	327	31	279	- 17 grs.
	Solids, ¹	728 grs.	780	52	888	160	861	143	721	- 7 grs.
S.	Water, .	48.3 oz.	53.5	5.2	59.3	11	61	13.7	43.5	- 4.8 oz.
	Urea, .	251 grs.	294	43	307	56	272	21	243	- 8 grs.
	Solids, .	626 grs.	757	31	786	160	770	144	690	+ 64 grs.
B.	Water, .	38 oz.	46.5	8.5	49.8	11.8	51.5	13.5	43	+ 5 oz.
	Urea, .	189 grs.	220	31	290	101	21.5	26	181	- 8 grs.
	Solids, .	392 grs.	446	54	538	146	505	113	414	+ 32 grs.

¹ This estimate of the solids is only approximate, having been calculated from the specific gravity by Christison's formula, viz., by multiplying the last two s by 2.33, and taking the product as representing the amount per 1000.

may fairly be put down to the effect of the drug. The experiments having thus been conducted on three different persons, neutralise many of the accidental sources of error. The small amount of urea normally excreted by prover B may in part be explained by his sedentary habits and obese tendency, as well as by the fact that his diet was very poor in nitrogen.

Of the increase of the urea elimination under the influence of potassium fluoride, therefore, there can be no doubt; and it would seem that this drug does not act as a mere eliminator of uræa, but actually increases the formation of urea through excessive destruction of tissue,—ostensibly the red blood-corpuscles.¹ The increase in the urea excretion is greater in the earlier than in the later stages of the administration of the drug; and, after discontinuing the medicine, it tends slightly below the normal amount.

¹ That the increased elimination of urea is not due to an increase in the general tissue waste seems evident from the fact that the body-temperature is slightly lowered, and the arterial pressure somewhat reduced without quickening of the pulse. Dr E. Woake's, in *Lancet*, p. 448, vol. i. 1881, having advocated the use of hydrofluoric acid in goitre, I was led to try the effect of sodium fluoride on a lad suffering from that disease, whose blood I had on several occasions examined hæmometrically, and I was much struck by the enormous reduction in the numbers of the red corpuscles which followed his taking this drug,—his red corpuscles falling in ten days from 4,880,000 per cb. mm. to 2,980,000 per cb. mm. I thereupon made a large number of careful observations in other cases, and found that this numerical reduction of the red corpuscles invariably attended the administration of the alkaline fluorides or the acid in large doses. Details of these observations, &c., are given in a paper by the writer in the *Indian Medical Gazette*, April, *et seq.* The corpuscular loss suffered by the provers during the taking of potassium fluoride was as follows:—W.'s = 1,260,000 corps. per cb. mm., B.'s, 1,460,000, S.'s 980,000, and P.'s (whose urea estimate is not given, as his duties, leading him to go out in the heat of the day, induced profuse sweating, which interfered with the due elimination of urea by the urine) 1,020,000 per cb. mm. The general loss, therefore, amounted to about one-fourth the total number of red corpuscles.

The bearing of this artificially produced anæmia on the therapeutical results of the use of hydrofluoric acid in goitre will be obvious. The proximate cause of this disease is now generally regarded as being a local plethoric, and St Lager (*Med. Chir. Rev.*, p. 24, ii. 1868) has collected cases in which the long exhibition of iron preparations was followed by bronchocele; it remains, however, to be shown to what extent iron prevails in the potable waters of districts where goitre is endemic. On this idea of vascular fulness, the action of hydrofluoric acid and the alkaline fluorides in reducing to a greater or lesser degree soft goitrous enlargements, is capable of explanation as a secondary result of the general anæmic condition produced by these drugs. As a consequence of the reduction in the general arterial pressure and diminished blood supply, shrinking of the enlargement will gradually ensue.

In two other cases hydrofluoric acid was given in doses of 1 to 2 drams of a $\frac{1}{2}$ per cent. solution (of the anhydrous acid) thrice daily, with an effect on the urea excretion generally similar to that just recorded. So that this alteration in the urea excretion would appear to be exerted by the fluorine element of the salt.

PRIMARY SARCOMA OF THE KIDNEY. By BERTRAM
C. A. WINDLE, M.A., M.D. (Dubl.), *Pathologist to the
General Hospital, Birmingham, and some time Demonstrator of
Anatomy and Histology, Royal College of Surgeons, Ireland.*¹

INTERESTING as all the primary growths of the urinary tract are, there are none which, both intrinsically and from their bearing on the etiology of tumours, are more worthy of study than the group which I purpose considering in this paper.

Having within the last few months had the opportunity of making a study of some cases, I have been led to examine the literature of the subject, and I append the result of my investigations in this direction in the form of a table.

I shall commence by giving brief details of the cases which have come under my own notice.

CASE I.—Specimen sent for inspection by W. Thursfield, M.D., of Bridgenorth, to whom I am indebted also for notes of the case.

C. W., male, æt. 34, first came under Dr Thursfield's care in the beginning of 1882. At this time he had been aware of the presence of a tumour for more than a year and a half, and had been seen by Dr Heslop of this town, who considered him to be suffering from a malignant tumour of the right kidney or liver, the disease being then too far advanced for an accurate location of the site. The tumour gave so much the sensation of fluctuation that paracentesis abdominis was performed, but no fluid obtained. Subsequently he was seen by Mr Lawson Tait who proposed an exploratory incision, which, being agreed to by Drs Heslop and Thursfield, was performed, and revealed the presence of an enormous solid tumour. Mr Tait informs me that as the patient had expressed a wish not to be subjected to any great risk this was not removed and the incision was closed up. He returned home, and there died from hæmorrhage from a vein on the surface of the tumour at a point in the latter which filled up a small portion of the incision which had not closed up. An

¹ Read before Birmingham and Midland Counties Branch of British Medical Association.

autopsy was with some difficulty obtained and performed by Dr Thursfield, with the following results:—

The abdomen was found to contain an immense tumour springing from the right side, dipping down into the pelvis and crossing the middle line to the opposite side. The vessels supplying this entered it from below, and it occupied apparently the site of the right kidney, which was nowhere visible. The caput cœcum coli and ascending colon were firmly adherent to its side. The liver was pushed up to close under the right clavicle and the heart under the left, the lungs being compressed backwards and very small and thin. The right suprarenal capsule could not be found. The left kidney was half as large again as normal, but otherwise appeared healthy. Its suprarenal was also normal. The pancreas was not to be seen, but a large quantity of a brain-like substance was found adherent to the hinder part of the inferior aspect of the diaphragm, springing from the front of the spinal column and passing behind and beneath the spleen. This last-mentioned organ was normal in size, but softened in substance. There were brain-like deposits in the mesenteric glands, and on the peritoneal surface of the small intestine in places.

The specimens sent to me for examination were as follows:—

1. *Liver*.—Weight 84 ounces, pale greenish-yellow colour, cut easily, and section appeared normal save for colour. Several soft nodules of a yellow colour scattered through organ, the two largest, each of which was of the size of a walnut, were situated one at the apex of the right lobe, the other in a similar position in the left.

2. *Mass from below Diaphragm*.—Weight, 20 ounces. Appeared like broken up brain substance. In parts nodules were seen, yellowish-white or pink in colour. Does not in any way resemble any normal organ.

3. *Tumour*.—This was of an irregularly spheroidal shape, and weighed within a few ounces of fifty pounds. Attached to one edge was the vermiform appendix and caput cœcum coli, containing some soft yellow faeces. At this corner there was a projecting nodule as large as a small cocoa-nut, which gave an indistinct feeling of fluctuation, but the remainder was hard and firm. From the flatter surface a tube hung, on dissecting which

up the kidney was reached. This was surrounded on all sides by the tumour, though at only a short distance from one surface. On dividing it no divergence from the normal was detected. On slicing the tumour the sensation was that of cutting firm fibrous tissue, and the appearances were as follows:—For the most part the cut surface was greyish and fibrous, other spots were yellow like beef-suet, others marbled grey and black, others reddish, whilst a few were white. In a small number of places there were soft pultaceous yellow patches. The projecting nodule already alluded to was formed of a semi-diffuent substance. Sections for microscopic examination were taken from various parts, and very widely differed from one another. They may be divided under three heads—

(1.) Spindle cells occupy some portions of the tumour entirely, but of the fragments which I have examined they are in the minority.

(2.) Round cells scattered in a matrix consisting of fibrous tissue in some parts the cells, in others the matrix, being in the ascendant. There are also a few characteristic fat cells with crystals to be seen here and there. These appearances are only found in the semi-diffuent nodule.

(3.) A tissue resembling a lipoma divided into numerous compartments by very dense and broad bands of fibrous tissue. This appears to form by far the larger portion of the tumour.

Liver.—A section of one of the larger nodules already mentioned shows a number of round and spindle cells, the former variety being in the majority. Between these there is a quantity of fatty débris, apparently the remnants of the liver belts.

Brain-like Mass.—Consists of a few spindle and large numbers of round cells. No trace of any remnant of the pancreas or other organ could be seen.

Kidney.—The first thing that attracts the attention on examining this organ is the number and large calibre of the vessels. Their walls are also much thickened. The uriniferous tubes contain fatty and broken down epithelium. Nowhere is there any evidence of invasion of the organ by sarcomatous tissue.

CASE II.—A section of the kidney in this case has been entrusted to me by Mr T. Law Webb of Ironbridge, Salop, under

whose care the patient was, and to whom I am indebted for the following notes of the case.

E. M. W., female, æt. 3 years 5 months, was a thin sickly child from birth, but about six or seven months before her death got better and became very fat. On July 31, 1882, had suddenly a severe "belly-ache," and vomited once or twice. The urine passed after this was bloody for two days. However, the child recovered partially, but had another similar attack in six weeks. Early in October a swelling was noticed in the left loin, which grew rapidly, the child dying on October 21, apparently from exhaustion and vomiting. The tumour was about the size of a foetal head at full term, of a soft brain-like consistence and colour, and having the attenuated kidney spread out upon its surface. The sarcoma tissue projected in masses into the infundibula, but did not seem to blend with the kidney substance anywhere, being more continuous with the pelvis and capsule. A portion was sent to Mr H. E. Butlin of St Bartholomew's Hospital, who made the following report:—"I have examined your tumour from hardened sections, and find it to be a round-celled sarcoma. It probably arose in the pelvis of the kidney. It is peculiar from the fact that the child increased so in size and that it was so rapidly fatal."

CASE III.—This was under the care of Dr Balthazar Foster in the General Hospital. By his permission I mention it for the purpose of tabulating it. I do not give it in full, as I am aware that it is shortly to be published with full clinical history. The patient was a male aged $3\frac{1}{2}$ years. The growth of the tumour had extended over one year and four months. It occupied the right side, and there were secondary deposits in the left orbit, over the left elbow, left supra-renal capsule, and spleen. These, as well as the original tumour, were composed of spindle cells.

In the following tables I have collected all the published cases which I have been able to discover. In their composition I was confronted by two difficulties. Firstly, that of selection. There can be but little doubt, as Lancereaux observes, that the greater part of the cases of cancer met with in children are really sarcoma. But the definitiveness of sarcoma of the kidney has only been recognised of late time. I have only tabulated such cases as seem to be most probably sarcoma. Secondly, as to

classification. Mr F. T. Paul, of Liverpool, who has recently made a very careful study of a number of cases, and who has been good enough to supply me with some information as to his results, has adopted the following arrangement :—

Of congenital origin—

(a) Round celled and do. with higher evolution.

1. Fibro-sarcoma.

2. Striped myo-sarcoma.

3. Other varieties.

(b) Adeno-sarcoma.

Of adult origin—

(a) Round celled.

(b) Other varieties (?)

He also remarks—“ Dividing into congenital and adult origin is only for convenience, and not intended to refer in any way to the ultimate origin of new growths.”

This seems to me to be as good a method of classification as can be devised at present. Nevertheless, I have preferred to arrange the cases which follow under five heads, viz. :—(1) Those composed chiefly of spindle cells, (2) of round cells, (3) containing striped muscular tissue, (4) other varieties, (5), microscopic appearances unknown. They will thus be of easy reference, and can be rearranged when a thoroughly satisfactory classification of tumours has been devised, should that halcyon day ever arrive.

[TABLE I.

TABLE I.—*Tumours chiefly Spindle Celled Microscopically.*

No.	Sex.	Age.	Dura- tion.	Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases
1.	M.	yr. m. 34 0 6	yr. m. 2 6	R.	50 lb.	Described in paper above.	Described above.	Pancreas (?) Liver. Mes- enteric glands.
2.	M.	3 6	1 4	R.	6 lb. 2 oz.	Free from all other organs save supra-renal capsule, which was infiltrated and at- tached to upper end. No signs of kid- ney tissue.	Spindle cells entirely.	Left orbit. Left elbow. R. ad- renal. Spleen.
3.	F.	55 0	...	R.	...	Grew in the pelvis of the kidney, of which the posterior part remained. Contained a cyst holding three litres.	Spindle cells entirely.	
4.	M.	0 7	...	L.	Large as child's head.	Consisted of two parts. On the left a cyst containing about $\frac{3}{4}$ litre of brown-red thick fluid. On the right a mass 14 x 10 x 6 cm. with thin but adherent capsule. At the lower part of this there was partially normal kidney tissue to the extent of 0.5 x 6 cm.	Spindle cells. A few remnants of kid- ney containing numerous tubules, with normal epi- thelium.	
5.	F.	2 6 0	3	L.	1980 grm.	30 x 25 cm. contained several old blood clots. In the upper part a collection of 100 grms. of dark thick chocolate- coloured fluid. Lower parts solid.	Spindle cells entirely.	

TABLE I.—*Tumours chiefly Spindle Celled Microscopically*—continued.

No.	Sex.	Age.	Dura- tion.	Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases
6.	F.	yr. m. 5 9	yr. m. 1 4	L.	12-14 lb.	67.0 × 70.0 cm. The tumour grew from the pelvis of the kidney and from the portion of renal tissue adjacent.	Spindle cells entirely.	No metastases.
7.	M.	76 0	...	R.	240 gm.	Consisted of two parts; spherical above (6.5 × 6.0 cm., total length 14 cm.), of which centre part was softened, and periphery partly compact partly spongy. This was cut off by septum from the lower part, which was a fatty kidney.	Fuso-cellular alveolar sarcoma. Some round cells.	Heart, especially right side. Pleuræ. Spleen, intestines, and mesentery.
8.	M.	0 10 0	6	L.	5 kgr.	A margin 1-2 cm. thick; in centre a red semi-putrid fluid. Kidney substance passed without any sharp distinction into that of tumour.	Sarcomatous tissue passed between the pyramids along the course of the smallest arteries.	

TABLE II.—*Tumours chiefly of Round-Cellled Elements Microscopically*—continued.

No.	Sex.	Age.	Duration.			Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases.
		yr. m.	yr.	m.	wk.					
5.	M.	3 3	1 0	0		Both	R. 3½ oz. L. 4 oz.	looks deep red, owing to the presence outside it, in the hilus of the kidney, of a softish deep red growth. Both kidneys much alike. No connection between growths. R. Purple-coloured growth pushing from pelvis to hilus. Did not invade organ. L. On section, one-half of pelvis shows same appearance as R. Besides this there are streaky deposits of white soft material running along pyramids, apparently in the course of the blood-vessels. Two rounded projections on surface. Kidneys large, and surface smooth. Purplish growth at hilus.	Round cells.	Prevertebral glands slightly enlarged.
6.	F.	4 0	3 0	0		Both	...		Round cells.	A retro-peritoneal gland at hilus of the kidney enlarged. Mesenteric glands enlarged, some caseous. Prevertebral gland in re-
7.	M.	1 6	0 8	0		Both	5 oz.	Pelvis of each filled with soft, deep purplish growth beneath the lining	...	

TABLE II.—*Tumours chiefly of Round-Cellled Elements Microscopically—continued.*

No.	Sex.	Age.			Weight or Size.		Macroscopic Appearance.	Microscopic.	Metastases.
12.	F.	yr. 21	m. 0	yr. 0	m. 8	wk. 0	7" x 4½" x 4½". Growth pierced capsule in no part. Upper part healthy for about as much as upper quarter of a normal kidney; youngest parts near cortex, oldest at about position occupied by apices of pyramids.	...	Liver (1) lungs. Renal vein. Glands at root of kidney.

TABLE III.—*Tumours containing Striated Muscular Tissue.*

No.	Sex.	Age.			Side.	Weight or Size.	Macroscopic Appearance.	Microscopic.	Metastases.
1.	M.	yr. 2	m. 6	yr. 2	m. 6	L.	1405 grms. 15 x 16 x 10-11 cm. Appeared like a considerably enlarged kidney, with very tough firm capsule; slightly nodular, with hilus, pelvis, and ureter. Kidney substance present in vicinity of pelvis (1.5 and thinning out towards convex surface of tumour. From this it was separated by a connective-tissue stratum, which started from, and was connected with, the extended kidney stroma.	Adeno-sarcoma, containing in the stroma striped muscular tissue.	None.

2. M.	1	3	0	3	Both	...	<p>L. 25 × 17 × 12 cm. At the upper part a portion of normal kidney.</p> <p>R. Normal, save for containing at its upper end a nodule 4 × 3.5 cm. in size.</p>	<p>Striped muscular tissue. Fibres small, long, and interwoven. No sarcolemma discovered. In other parts, but not so plentifully, typical sarcomatous tissue.</p>	<p>Small nodules under peritoneal covering of diaphragm. Striped muscular sarcoma tissue.</p> <p>Nodules of sarcoma in liver.</p>
3. F.	1	5	...	...	Both	...	<p>Unaltered portions of right kidney attached to growth, but well marked off from it.</p> <p>Tumour size of peach in left kidney.</p>	<p>R. Striped muscular tissue. Round and spindle cells.</p> <p>L. Round and spindle cells. No muscular tissue.</p>	
4. M.	1	4	...	...	...	2770 grms.	<p>At the posterior edge, which showed a kind of hilus, there was, apparently in the middle of the under side, a well-projected piece of kidney, which projected freely but was firmly united to the tumour.</p>	...	
5. M.	1	4	0	2½	R.	7½" × 4½" × 4½"	<p>Attached to superior and anterior surface of kidney, the substance of which was not invaded. There was a depression in which tumour lay where parenchyma was exposed.</p>	<p>Striated muscular fibres without sarcolemma. Round and spindle cells also present.</p>	

TABLE III.—*Tumours containing Striated Muscular Tissue*—continued.

No.	Sex.	Age.	Dura- tion.	Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases.
6.	...	yr. m. ...	yr. m. ...	Both	R. 7" × 5".	R. Sharply defined from kidney, but capsule continuous over both. Tumour is attached to hilus, so that pelvis is completely obliterated. L. A smaller tumour attached to the hilus.	R. Striped muscular fibres and round cells. L. Composed largely of round cells, occasional fasciculi of spindle cells, widely distributed through it is striped muscular tissue.	
7.	M.	1 1 0	3-4	R.	1 lb. 13½ oz.	No vestige of kidney structure to naked eye. Consistency of tumour everywhere soft, at upper part almost diffuent, so that when washed a ragged walled cavity was left.	Spindle cells and striated muscular fibres.	
8.	...	0 7	...	Both	Each size of fist.	Tumours partially covered by capsules. A third attached loosely by fibrous tissue to lower end of right.	*All three contained muscular tissue.	

9.	M.	1	7	...	L.	16 cm. long.	<p>Capsule thin; on detaching it a large white mass is seen through thin layer of cortex on convex border. Tumour (7 cm. each way) occupies centre of kidney, which covers it as a capsule; thinnest at the outer border. At the margins the tumour can be seen penetrating the kidney tissue, strands of which separate the advancing portions. Pelvis and calyces somewhat compressed; ureter opens directly below the centre of the mass.</p>	<p>Spindle cells, striated muscular fibres. No sarcolemma.</p>	...
10.	F.	3	3	...	L.	15 x 7.5 cm.	<p>On under surface natural kidney substance for 2-3 cm. near hilus. At upper part two pyramids of kidney substance are surrounded by the new growth. Wall of renal vein rough, irregular, and covered with bits of soft greyish tissue.</p>	<p>Chiefly round cells. Spindle cells also present. In variable numbers striated muscular fibres as case above (Table III. No. 9), but not so numerous.</p>	<p>Firm greyish-white mass larger in R. aur. vent. orifice (25 x 12 mm.), another in pulmonary artery, and others in right branch. These contained striated muscular fibres. No metastases in lungs.</p>

TABLE III.—*Tumours containing Striated Muscular Tissue—continued.*

No.	Sex.	Age.	Dura- tion.	Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases.
11.	M.	yr. m. 3 3	yr. m. 0 7	L.	5500 grms.	...	Cells of various shapes, ranging between those of oat-like appearance and striated cells like voluntary muscular fibres. No sarcolemma.	Liver.

TABLE IV.—*Tumours of Microscopic Appearances other than those already tabulated.*

No.	Sex.	Age.	Dura- tion.	Side.	Weight or Size.	Macroscopic Appearances.	Microscopic.	Metastases.
1.	F.	yr. m. 5 0	yr. m. 0 4-5	L.	6 kgr.	A tumour of the consistence of brain. On section consisted in parts of soft nodules, in parts of cavities with sanious contents. It had grown around the atrophied left kidney.	Myxo-sarcoma, hæmorrhagic. Contained many young muscular fibres.	One deposit in pleura.

2.	F.	25	0	0	4	Both	3 lb. (L.)	L. Capsule much thickened. Pelvis partially obliterated, the remaining cavity being filled with a grumous matter.	"Sound connective tissue corpuscles embedded in an homogenous matrix." Some renal tissue left.	Heart. phragm.
3.	...	1	7	0	5	L.	...	...	Myxo-sarcoma.	

TABLE V.—*Tumours whose Microscopic Appearances are not specified.*

No.	Sex.	Age.	Duration.		Side.	Weight or Size.	Macroscopic Appearances.	Metastases.	
1.	F.	yrs. 5 mh. 0	yr. ...	mh. wk. ...	L.	As large as a child's head.	...	Porta hepatis.	
2.	F.	8 0	...	...	R.	As large as a child's head.	...	Liver.	
3.	F.	3 3	0 1	2 2	...	...	Cysts on upper surface.		
4.	...	0 10	0 0	4 4	R.	Large as child's head.	...		
5.	F.	7 0	0 4	0 0	L.	...	Lobulated. Some lobes like brain substance. Others purple.		
6.	...	3 3	...	...	...	5 lb. 9 oz.	...		
7.	Premature child.		...	...	L.	...	...	Liver and left supra-renal capsule.	

REFERENCE TO TABLES.

TABLE I.

- 1 and 2. In paper above, Cases I. and III.
3. Koch, E.—*Beiträge zur Kenntniss der primären Nieren Tumoren, bes. der Sarcome. Diss.*, Halle. Abstract in *Hirsch's Jahresbericht*, vol. xiii. 1, p. 273.
4. Baginsky, A.—*Deutsche Med. Wochenschrift*, 10, 1876. Abstract in Schmidt's *Jahrbuch*, 1879, Bd. clxxxiv., No. I. p. 86, and *Lond. Med. Rec.*, vol. iv. p. 322.
5. Martineau.—*Gaz. des Hôp.*, 39, 1875. Abstract, Schmidt (as above, No. 4) p. 90.
6. Neumann.—Über das primäre Nierensarcom, *Deutsches Archiv für Klinische Medicin*, vol. xxx.
7. Fenoglio, Ignazio.—Sarcoma Primitivo Del Rene in Vecchio di 76 Anni, *Gazetta degli Ospitali*, 6 Settembre 1882, N. 72.¹
8. Audain.—*L'Union Med.*, 56, 1875. Abstract, Schmidt (as above, No. 4), p. 90.

TABLE II.

1. In paper above, Case II.
2. Berner.—Tilfælde af stort nyresarcom Nos et Barn., *Norsk. Mag. for Lægevid Forhandl.*, p. 51. Abstract, *Hirsch's Jahresbericht*, vol. xvi. Bd. ii. p. 207.
3. Pasturaud and Garsaux.—*Bull. de la Soc. Anat.*, 3 sér. x. 2, p. 262, 1875. Abstract, Schmidt's *Jahrbuch*, 1879, Bd. clxxxiv., No. 1, p. 89.
- 4, 5, and 6. Abercrombie.—*Trans. Path. Soc. London*, vol. xxxi. p. 168.
7. Abercrombie.—*Trans. Path. Soc. London*, vol. xxxii. p. 205.
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11. Tellegen.—Groningen, 1875. Abstract in Schmidt's *Jahrbuch*, 1879, Bd. clxxxiv., No. 1, p. 88.
12. Barker.—*Med. Chir. Trans.*, 1880, pp. 181 *et seq.*

TABLE III.

1. Kocher.—*Deutsche Ztschr. f. Chir.*, ix. 3-4; Jan. 1878. Abstract, Schmidt's *Jahrbuch*, 1879, Bd. clxxxiv., No. 1, p. 91, and *Hirsch's Jahresbericht*, vol. xiv. 2, p. 419.
2. Cohnheim.—*Virchow's Archiv*, lxxv. 1, p. 64, 1875. Abstract, Schmidt (*ut supra*), p. 91; *Lon. Med. Rec.*, iv. p. 448.

¹ For obtaining this paper for me and kindly furnishing me with a translation of it, I have to express my acknowledgments to Mr Samson Gamgee, F.R.S.E.

3. Eberth.—Virchow's *Archiv*, Bd. lv. s. 518. Quoted in Eve's paper, *Trans. Path. Soc. Lond.*, vol. xxxiii. p. 315; and *Nouveau Dict. de Med. de Chirurg. Pratique*, article "Rein."
4. Marchand.—Virchow's *Archiv*, Bd. lxxiii. 1878, and same references as Table III. 3 (above).
- 5 and 6. Eve.—*Trans. Path. Soc. Lond.*, vol. xxxiii. pp. 312 *et seq.*
7. Dawson Williams.—*Trans. Path. Soc. Lond.*, vol. xxxiii., 317 *et seq.*
8. Landsberger.—*Berl. Klin. Wochenschrift*, 1877, No. 34, s. 497. Quoted by Eve and Neumann.
- 9 and 10. Osler.—*Journal of Anat. and Phys.*, vol. xiv. 1879, pp. 229 *et seq.*
11. Huber and Boström.—*Deutsches Arch. für Klin. Med.*, xxiii. p. 205.

TABLE IV.

1. Elben.—Zur casuistik der Nierengeschwülste, *Würtemb. Med. Corr. Bl.*, No. 14. Abstract, Hirsch's *Jahresb.*, xv. 2, p. 213.
2. Porter.—*New York Med. Rec.*, Jan. 14, 1882.
3. Smith.—*New York Med. Rec.*, Sept. 18, 1880.

TABLE V.¹

- 1 and 2. Sturm.—Quoted in Neumann's papers as i. 6.
3. Geddings.—Quoted in Neumann's papers as i. 6.
4. Hahn.—Quoted in Neumann's papers as i. 6.
5. Edgerly.—*Boston Med. and Surg. Jour.*, vol. civ., No. 6, p. 131.
6. Skene.—*Am. Jour. of Obst.*, vol. xii. p. 741.
7. Jacobi.—*New York Med. Jour.*, vol. xxx. 1879, p. 524.

The results of these tables may be summarised as follows:—

Sex.—Out of a total of 37 cases in which this point is noted, 21 were females, 16 males. Amongst spindle-celled tumours, 5 were males, 3 females; round-celled, 4 males, 8 females; rhabdomyomata, 7 males, 4 females.

Age.—It has long been a recognised fact that these tumours are peculiarly obnoxious to infant life, and yet they are by no means confined to it. Thus, the youngest subject in which one was found was a premature child, the oldest a male of seventy-six. The average for the whole number is a trifle under ten years and two months, but it is very interesting to observe how much it differs in the various forms of the disease. Thus, in the first table (spindle cells) the average is 23 years (nearly),

¹ Cases in this Table come under two categories—1st, Those in which the original paper does not mention the appearances; 2d, Those in which I have been unable to consult the original paper, and in which the abstract is silent as to the microscopic nature.

in the second (round cells), 11 years $3\frac{1}{2}$ months; in the third (rhabdomyomata), 1 year, $1\frac{3}{4}$ months; in the fourth, 10 years and 6 months.

The following analysis shows the number occurring at various ages :—

Number	Table I.	Table II.	Table III.	Table IV.	Table V.	Total.
Under 1, . .	2	1	1	...	2*	6
„ 2, . .	...	1	6	1	...	8
„ 3, . .	1	2	1	...	...	4
„ 4, . .	1	2	2	...	2	7
„ 5, . .	...	1	...	...	...	1
„ 10, . .	1	2	...	1	3	7
„ 20, . .	...	...	...	...	...	...
„ 30, . .	...	1	...	1	...	2
„ 40, . .	1	1	...	...	...	2
„ 50, . .	...	...	...	...	...	...
Over 50, . .	2	1	...	...	...	3

* One a premature child.

From this we learn that 33 of 40 occurred before the tenth year, and of this 33 twenty-six before the fifth year.

Duration.—This is a factor quite impossible to fix. Such as it is, it simply indicates the length of time which has intervened between the first time the tumour was noticed and the death of the patient. Many, doubtless, if not most, of the cases are congenital; of one there can be no doubt (Table V. Case 7). The period during which the tumour has been known to be growing ranges between a few weeks and three years.

Side.—The left side was attacked in 14 cases, the right in 12, and both in 11. The round cell and rhabdomyomatous varieties appear to be those in which the disease is bilateral. In the former the left was affected in 2 cases, the right in 4, both in 5; in the latter, left 4, right 2, both 4.

Weight and Size.—This, of course, varies considerably. Speaking generally, these tumours appear to rapidly reach very enormous dimensions. The first case in this paper is a striking instance in point.

Macro- and Microscopic Appearances.—The condition and site of the kidney, or remains of kidney, in these cases, is the chief point to which I wish to call attention. It is apparently the

exception to find none of the organ remaining, and when present it seems to exist under three well-marked conditions, viz.:—

1. Forming a pseudo-capsule for the growth.
2. Infiltrated by the growth.
3. Incapsulated by the growth.

It appears to me that a consideration of the tables will afford a clue to the cause of these differences.

As to the first. In these the growth commences in the hilus and spreads on the inside of the pelvis in every direction without invading the proper structure of the organ. Thus, finally the kidney becomes expanded into a mere shell covering the convex surface of the neoplasm. In Table II. Case 6 a purplish growth exists at the hilus. This represents the first stage. The second case narrated in this paper shows the last, where the attenuated kidney was spread out upon the surface of the tumour. The sarcoma tissue projected in masses into the infundibula, but did not seem to blend with the kidney substance anywhere.

The second class of cases is perhaps only a variety of the first. In it the growth, instead of merely pushing the kidney before it, invades it. This it does in the course of the blood-vessels between the pyramids (see Table II. Case 5). In process of time this infiltration may extend so far as to obliterate all traces of renal tissue.

The third class includes those cases in which the growth has commenced at the hilus and spread along the outer surface of the capsule, thus enclosing the kidney in the centre. The first case in this paper is a good instance of this class, as is that given in Table IV. Case 1.

As to frequency of occurrence, the order seems to be infiltration (second class), expansion (first class), incapsulation (third class), the term in each case referring to the kidney.

These remarks must be taken with a reservation in favour of the rhabdomyomatous tumours, which seem to follow different rules. About these singular tumours so much has been written that I only purpose lingering over their consideration for a very short time.

Apart from their microscopic appearances, the chief characteristics of this form of growth seem to be as follows:—They

are tumours of very early life, probably congenital, frequently bilateral, seldom actually invading the kidney, but more often attached to it, and occasionally causing absorption or atrophy of its tissue.

Cohnheim, as is now well known, regards them as the development of a portion of primitive muscular plate included in the rudimentary kidney by faulty segmentation. My friend Professor Haycraft has suggested to me that possibly the fibres in these tumours may not be true striated muscular fibres, and that the appearances seen in them may be simply due to ribbings of the surface of a tissue which is non-contractile. Certainly they appear never to have a sarcolemma.

Metastases are stated to have occurred in 17 out of 41 cases occurring in the following proportions in the various forms:—Spindle cells, 3 in 8; round, 5 in 12; rhabdomyomata, 4 in 11; others, 5 in 10. The liver was more frequently attacked, containing secondary deposits in six certain and one doubtful case. The retroperitoneal glands were affected five times, the mesenteric four. The heart contained deposits in three cases, in one of which the metastatic growth consisted of a mass containing muscular fibres fixed in the right auriculo-ventricular orifice. The diaphragm, adrenals, spleen, and lungs were each invaded twice, and the following organs, &c., once:—pancreas, intestines, pleura, renal vein, orbit, tissues about elbow.

THE TRANSVERSE MEASUREMENTS OF HUMAN RIBS. By R. J. ANDERSON, M.A., M.D., *Professor of Natural History, Queen's College, Galway.*

AN examination of the ribs shows generally an increase in length from the first to the seventh or eighth, and a diminution from the seventh or eighth to the twelfth. An increase in breadth from the second to the seventh, and then a diminution. The latter statement is not quite accurate. The breadth of the first rib near the sternal end exceeds greatly the breadth of all the others, the seventh excepted; the seventh comes next, then in order the fourth, sixth, third (the sixth and third nearly equal), then fifth, eighth, second, ninth, tenth, &c. So that there is a gradual increase from the second to the fourth, and an increase from the fifth to the seventh, the fifth being less than the fourth at the sternal end. The fifth, third, sixth, and seventh are nearly equal (the seventh exceeds the fifth by one-half millimeter, the others by a less amount, but the fourth exceeds all these. The measurement of the third is less than any other rib up to the eighth. At a distance of two centimetres the third, fifth, sixth, and seventh are nearly equal; but the third and fifth are nearly equal, and exceed the sixth and seventh which are equal. The transverse measurement of the fourth rib is greater than those just mentioned, and the second exceeds the eighth and succeeding ribs. At three centimetres the order is fifth, fourth, third, and sixth, second, seventh, eighth, ninth, tenth. At four centimetres—fourth, third, sixth, fifth, second, seventh, eighth, ninth, tenth. At five centimetres—sixth and fifth, third and second, seventh, eighth, ninth, tenth.

In the first rib the breadth falls off at the groove for the sub-clavian artery, and often increases slightly before this.

Second—breadth greater at junction of anterior and middle third.

Third—a marked diminution at 6 cm. from sternal end.

Fourth—diminution at 5 cm.

Fifth—diminution at 4–5 cm.

Sixth—diminution at $3\frac{1}{2}$ cm.

Seventh—diminution at 1 cm. 20 cm. at the end, 15 at 5 cm.

Eighth—a slight diminution.

Ninth—an increase at 5 cm., nearly parallel up to this.

Tenth—increase at 5 cm. from end.

Eleventh—immediate increase.

Twelfth—abrupt increase.

The arrangement above noted holds in by far the greater number of cases examined. There are, however, exceptions, but these seem not to be numerous. Exceptions occur under the following circumstances:—If the eighth rib be strong near the sternal end, the breadth of the seventh near its extremity is smaller. A rib in a few cases was observed to resemble its neighbours in its general character, just as we find well-marked characters of a first rib in a second when the first is abortive. Measurements have been made in thirty-five sets; in many others examined by me the rules seem to hold.

The means of the measurements are appended.

It may further be observed that in several works on osteology, where the plates are drawn from nature, the conditions above described appear quite manifest.

Note.—One point in connection with the posterior part of a rib seems to deserve attention, viz., the straight course of the upper border of the neck and the curve at the lower border. This will enable the junior student at once to distinguish the side to which a rib belongs, and of course it is most useful for the twelfth.

[MEANS

MEANS OF MEASUREMENTS OF BREADTHS OF RIBS GIVEN IN
MILLIMÈTRES.

	At end.	1 cm.	2 cm.	3 cm.	4 cm.	5 cm.	6 cm.	7 cm.	8 cm.
First Rib, .	19	19·17	19·34	19·13	20	16	16	18·5	...
Second Rib, .	13·84	13·7	14·05	14·67	13·8	16·2	15	14	20
Third Rib, .	17·13	16·47	15·93	15·16	14·9	14·2	14·4	14	15·5
Fourth Rib, .	17·28	17·64	17·81	16·44	15·7	15·4	15·2	14·5	17
Fifth Rib, .	16·66	16·24	15·96	17·3	14·07	14·8	14·67	14	14·5
Sixth Rib, .	17·12	16·54	16·55	15	14·8	14·9	14·7	14·7	13·5
Seventh Rib, .	18·5	16·82	15·58	14·4	13·6	13·94	14	13·8	15·37
Eighth Rib, .	14·72	14·04	13·38	12·3	12·5	12	13	14	13
Ninth Rib, .	12·3	11·83	11·32	11·24	11·35	12	12·3	13·2	13·25
Tenth Rib, .	11·3	11·45	11·53	12	12	13	12·2	14	14·25
Eleventh Rib, .	9·33	10·3	12	12	12·3	12·3	12·6	13	14
Twelfth Rib, .	8	9	9	9	13	13·7	12	...	...

ON A METHOD OF DETERMINING THE POSITION OF THE FISSURE OF ROLANDO AND SOME OTHER CEREBRAL FISSURES IN THE LIVING SUBJECT.

By ARTHUR W. HARE, M.B., M.C., *Assistant to the Professor of Surgery, University of Edinburgh, Senior President of the Royal Medical Society.*

DURING the last quarter of a century the surface of the brain and its relation to external parts, from being a "terra incognita," have, step by step, come to be accurately described fields of anatomical science. The feeling has of late been ably expressed¹ that this knowledge should be more largely used in the interests of surgical practice than has in the past been the case, and it is in the hope of furthering this end that the following pages are written.

The chief interest of the question centres in the exact determination of the position and course of the fissure of Rolando in their relation to external landmarks; and with this object a series of measurements on the dead subject was, through the kindness of Professor Kundrat, carried on in the Laboratory of the Pathological Institute in Vienna during the winter session 1882-83. My hearty thanks are also due to Professor Chiene, who first proposed this investigation, and gave me valuable assistance and encouragement in carrying it out.

Up to the present, authors on this subject have chiefly taken the coronal suture as their basis of calculation, and are pretty much at one as to the distance of the upper end of the fissure behind this point, stating it to be approximately 2 inches (Broca, Turner, Féré, Championnière). Professor Turner² shows that it may vary as much as half an inch, and he and Broca³ recognise that in the female subject the measurement will be somewhat less than in the male.

It would thus be of practical importance if a scale could be established which should include these variations by making

¹ Dr J. A. M'Dougall, *Ed. Med. Jour.*, Oct. 1883.

² "Relations of Convolutions to Skull and Scalp," in the *Journal of Anatomy and Physiology*, November 1873, pp. 144-145.

³ *Sur la Topographie Cranio-Cérébrale*, 1876, p. 17.

them subject to approximate calculation. If, for instance, we take the cerebrum as a whole, ascertain the surface distance between its two extremities in the middle line, and the surface distance of the upper end of the fissure of Rolando from one extremity, we may expect the latter distance to be in a number of cases a nearly constant fraction of the former.

Professor Turner¹ has pointed out the value of the external occipital protuberance as a landmark giving definite information as to the subjacent brain, and this prominence and the glabella² represent respectively the posterior and anterior limits of the cerebrum. The distance between these points was compared with the distance between one of them and a point corresponding to the summit of the fissure of Rolando, and a nearly definite relation was found to exist between them, which applies alike to heads of large and small dimensions, and which obviates the differences of form occasioned by the varied development of the

¹ *Op. cit.*, p. 142.

² *Cf. Broca, op. cit.*, p. 8

bones forming the vault of the skull¹ in their antero-posterior dimensions.

The method adopted was as follows:—Fresh trunkless heads were taken and the scalp shaved. A hole was then bored deeply into the frontal bone at the glabella, and another at the external occipital protuberance, into each of which a wooden peg was driven (in fig., *a* and *b*). A piece of string was drawn tightly between the two pegs, lying in the mesial line of the head; and along the line so defined an incision was made down to the bone. The string was next applied to the right lateral aspect of the head, and was made to mark out a straight line between the two pegs, which in its course passed over the external angular process of the frontal bone. Along this line also an incision was carried down to the bone. The skull was now sawn through in the two lines so marked out, and the portion of skull thus detached was removed, exposing nearly the whole of the lateral aspect of the right hemisphere of the cerebrum (see fig.). The dura mater was cut through in the same lines and removed, as was also the pia mater, after it had been detached from the brain substance by directing a stream of water beneath it. The fissures and convolutions were then very distinctly traceable. A long pin was now passed through the free margin of the divided scalp and fixed upright in the falx at the point where the upper end of the fissure of Rolando was found to be situated (see fig., “1”). This method was carried out in a series of eleven heads. The distance between the two pegs measured upon the middle line of the scalp, and the distance of the (Rolando) pin from the anterior (glabella) peg were in each case ascertained and compared; and it was found that the latter formed a percentage of the former, which varied remarkably little in the series of heads examined, although amongst them were heads of the most varied size and proportions (see Table I.).

The distance from the glabella to the fissure was on the average 55·7 per cent. of the distance from the glabella to the external occipital protuberance. The fissure varied slightly in its position to either side of the point so determined, but in no case did this variation amount to $\frac{1}{3}$ of an inch.

¹ Cf. Huschke, *Schädel, Hirn, und Seele*, p. 9.

It is possible, by following out the relation thus indicated, to localise on any head the position of the upper extremity of the fissure by measuring the line from glabella to occiput, and taking the percentage of it above indicated (see Table II.).

The length of the fissure of Rolando was in each case measured by placing a pin in either extremity, and measuring a piece of twine stretched straight between the two. This measurement varies but slightly in different brains (from $3\frac{1}{8}$ inches to $3\frac{1}{2}$ inches); the average for the eleven heads examined was $3\frac{3}{8}$ inches.

It was thought that the general direction of the fissure could be conveniently ascertained by noting the angle which its axis,¹ as represented by the line between its extremities, forms with the mesial line of the head. This was measured and recorded in the case of each head examined. The angle so produced is found to vary from 60° to 73° , the average being 67° in the eleven cases; so that in the case of maximum variation (60°) found, there is a difference of 7° from the average. This represents, at a distance of $3\frac{3}{8}$ inches (the length of the fissure), a possible variation of $\frac{7}{16}$ of an inch in the position of the lower extremity of the fissure as localised by this method. Practically, this variation is unimportant, for at other parts of the fissure it is less in amount; and even at the lower extremity it would not interfere with certainty in operation, as the small-sized trephine² has a diameter of $\frac{1}{8}$ of an inch, and the larger size 1 inch.

The preceding points having been ascertained, certain other measurements were made. Pins were passed through the cut margin of the scalp in the mesial line into the coronal and lambdoidal sutures, and their distances from the fissure of Rolando measured. Its distance from the coronal suture varies from $1\frac{3}{8}$ inch to $2\frac{1}{4}$ inches (average $1\frac{7}{8}$ inch in eleven heads), thus closely corresponding with Professor Turner's measurements (*vide supra*); but differing from the figures given by Championnière,³ who states the distance as $2\frac{1}{3}$ inches. This, however, it

¹ "Ligne rolandique" of Championnière. See *Sur la Trepanation guidée par les Localisations Cérébrales*, 1878, p. 105.

² Instruments made by Messrs Young, Edinburgh.

³ *Op. cit.*, p. 107.

would seem, arises from M. Champiounière's differentiation of the actual extremity (*extrémité réelle*) of the fissure, from that it would have had were its course straight; and it is to this latter hypothetical extremity that he ascribes the more posterior position.

The fissure, however, has two curves, arranged in a sigmoid manner, each curve deviating about equally from its main axis; hence the hypothetical extremity must be deemed to be superfluous.

Various methods have been adopted to make the brain of firm consistence before opening the skull, so as to ensure exact measurement or delineation of its surface. Heftler¹ injected a mixture of glycerine, carbolic acid, and chloride of zinc into the carotid arteries some days before opening the skull. Féré froze the head and brain before commencing—a good method if the temperature can be constantly kept low; if this is not achieved, however, the brain becomes much more diffuent on thawing than if it had never been frozen. In the heads which I examined the object was attained by early dissection, which was within thirty hours of death in most cases; and I found on opening the skull, in every case but one, that the brain retained sufficient consistence to prevent any material alteration in its relations.

Of the annexed tables, No. 1 shows some of the chief proportions and measurements of the heads which came under my observation; and No. 2 supplies the surgeon with the position of the upper extremity of the fissure of Rolando in heads of ordinary size; the angle at which the fissure runs may be approximately measured by the eye; but, in cases where operation is decided on, a simple arc will immediately supply the line of the fissure with considerable accuracy.

ADDENDUM.

On the Position of other Fissures of the Brain Surface.

The parieto-occipital fissure varies considerably in its relations to other features of the brain, and to the cranial bones of the

¹ Quoted by Broca, *op. cit.*, p. 12.

vault. Thus its distance from the fissure of Rolando varied from $1\frac{1}{2}$ to $2\frac{1}{4}$ inches, the average in eleven heads being $1\frac{7}{8}$ inches.

MM. Broca and Bischoff¹ make the parieto-occipital fissure correspond, as a rule, with the lambdoidal suture, and in this point disagree with Professor Turner, who places the fissure about 0·7 or 0·8 of an inch in front of that suture. Professor Ecker states² that he found the point of that suture about 7 mm. behind the median end of the fissure.

In one of my cases the fissure coincided with the lambdoidal suture; but in all the other cases (ten in number) it was anterior to that suture, the average measurement being $\frac{5}{8}$ inch, so that my observations closely approximate to those of Mr Turner. To determine its position in the living subject it is better, first, to define that of the fissure of Rolando, and to take a point $1\frac{7}{8}$ inches behind it (see Table I.), than to make a separate calculation of its position in the same way as for the fissure of Rolando. This is due to its varied position on the brain;³ for it is by no means so constant in its cerebral relations as the other fissures of the cortex.

The position of the commencement of the fissure of Sylvius was also ascertained in each of the heads examined. It has an almost exact relation to the external angular process of the frontal bone, being $1\frac{1}{8}$ inch posterior to that point; and in the eleven heads measured the greatest deviation from this amount was $\frac{1}{8}$ inch.

Subsequently observations were made as to whether the brain is bilaterally symmetrical as regards the position of the more important sulci. The fissure of Rolando was found to run symmetrically on both hemispheres in all cases but one, where the upper end of the left fissure was $\frac{1}{8}$ inch posterior to the same point on the right hemisphere. The commencement of the fissure of Sylvius was bilaterally symmetrical in all cases, but its upward course varied in length and direction on the two sides. Marked variations were present in the case of the parieto-occipital fissures of the two hemispheres, the central ends of which were more frequently found at different levels than opposite one another.

¹ See Broca in *Revue d'Anthropologie*, vol. ii. (1876).

² *Archiv fur Anthropologie*, ix. (1876), p. 72.

³ See Turner, *op. cit.*, p. 145.

TABLE No. I.

Head.	Sex.	Circumference.		Diameter.		Percentage relation of Diameters.	General Type of Head— Dolichocephalic below 80, Brachycephalic 80, and upwards.	From Glabella to Fissure of Rolando.	From Glabella to External Occipital Protuberance.	Percentage relation of these measurements.	Variations of each head from 55.7 per cent. the Average.	Representing a Deviation in inches from the Average.	Angle between axis of Rolando and Great Longitudinal Fissure.	Variation from 67° the Average.	Representing Surface Deviation at a Distance of 3½ inches.	Length of Fissure of Rolando.	Distance behind Coronal Suture.	From Fissure of Rolando to the Parieto-occipital Fissure.	From Lambdoidal Suture to Parieto-occipital Fissure.	External Angular Process of Frontal Bone to opposite Commencement of Sylvian Fissure.
		in.	in.	Interparietal.	Antero-posterior.	percent.		in.	inches.	percent.	percent.	inches.	degrees.	degrees.	inches.	inches.	inches.	inches.	inches.	inches.
1.	♀	19½	6½	7½	87.7	Brachycephalic,	6½	11½	53.8	1.9	.22	70	3	1½	3½	1½	2	½	1½	1½
2.	♂	21½	6	7½	78.7	Dolichocephalic,	7½		57.6	1.9	.22	73	6	¾	3½	1½	2½	¾	1½	1½
3.	♂	21½	6½	7½	81.9	Brachycephalic,	6½	11½	56.3	0.6	.07	70	3	1½	3½	2	1½	1½	1½	1½
4.	♂	20½	6½	7½	79	Dolichocephalic,	6½	11½	55.4	0.3	.03	73	6	¾	3½	1½	2½	¾	1½	1½
5.	♂	21½	6½	7½	82.2	Brachycephalic,	7½	12½	56.5	0.8	.09	60	7	1½	3½	2½	2	1½	1½	1½
6.	♂	22½	6½	8½	73.6	Dolichocephalic,	7½	12½	55.3	0.4	.04	61	6	¾	3½	1½	1½	1½	1½	1½
7.	♀	20½	6	7½	80	Brachycephalic,	6½	12½	53.0	2.7	.32	65	2	1½	3½	1½	1½	1½	1½	1½
8.	♀	20½	5½	6½	81.4	Brachycephalic,	7½	12½	57.0	1.3	.15	68	1	1½	3½	2½	2½	1½	1½	1½
9.	♂	21½	6½	7½	86.6	Brachycephalic,	7	12½	54.9	0.8	.09	67	...	...	3½	2	2	1½	1½	1½
10.	♂	20½	5½	7½	75.9	Dolichocephalic,	7½	12½	57.6	1.9	.22	69	2	1½	3½	2½	2½	1½	1½	1½
11.	♀	20½	5½	7½	78.3	Dolichocephalic,	7½	12½	57.0	1.3	.15	67	...	...	3½	2	2½	...	...	1½
				Average,					55.7	...	...	67	...	...	...	8½	1½	1½	1½	1½

TABLE No. II.

IN A HEAD WHERE THE

Distance from Glabella to External Occipital Protuberance is—		The Fissure of Rolando will lie behind the Glabella—
11 inches,	at 55·7 per cent.,	$6\frac{1}{10}$ inches.
$11\frac{1}{4}$ ”	” ”	$6\frac{3}{10}$ ”
$11\frac{1}{2}$ ”	” ”	$6\frac{2}{5}$ ”
$11\frac{3}{4}$ ”	” ”	$6\frac{1}{2}$ ”
12 ”	” ”	$6\frac{3}{5}$ ”
$12\frac{1}{4}$ ”	” ”	$6\frac{4}{5}$ ”
$12\frac{1}{2}$ ”	” ”	7 ”
$12\frac{3}{4}$ ”	” ”	$7\frac{1}{10}$ ”
13 ”	” ”	$7\frac{1}{5}$ ”
$13\frac{1}{4}$ ”	” ”	$7\frac{3}{10}$ ”
$13\frac{1}{2}$ ”	” ”	$7\frac{1}{2}$ ”
$13\frac{3}{4}$ ”	” ”	$7\frac{3}{5}$ ”
14 ”	” ”	$7\frac{7}{10}$ ”
$14\frac{1}{4}$ ”	” ”	$7\frac{9}{10}$ ”
$14\frac{1}{2}$ ”	” ”	8 ”
$14\frac{3}{4}$ ”	” ”	$8\frac{1}{5}$ ”
15 ”	” ”	$8\frac{3}{10}$ ”

NEW FORMS OF NERVE TERMINATIONS IN MAMMALIAN SKIN. By GEORGE HOGGAN, M.B. (Edin.) (PLATES VIII., IX.).¹

IMPROVED methods of investigating nerve terminations by means of solutions of gold have now been so long at our service, and so many indefatigable investigators have been working in this field of research, that it is rather surprising to be able to discover forms hitherto unrecognised in the skin of mammals. Such a discovery becomes all the more interesting, especially to comparative anatomists and to evolutionists, when it is made in an animal having peculiar habits, to which it may be possible in the future to refer peculiarities of conformation in the nerve terminal organs.

The one animal in which I have as yet found those new forms of nerve termination is the Raccoon, or *Procyon lotor*, the *Doglike Washer*, so named from its remarkable habit of dipping each morsel in water before eating it. This habit ought to be continually borne in mind during the future investigations that will be made into these forms, as they are almost certain to be found in some other animals, near relatives of the Raccoon. The method of preparation used by me combines the recommendations of many investigators, and every step in it is varied as much as possible, so as to insure some successful preparations with so notoriously an uncertain reagent as gold solution has hitherto shown itself to be. To enumerate all the modifications I employ would require in itself a special paper. Let it suffice to say that in all cases I treat the fragments of tissue with (Ranvier's suggestion) the juice of a fresh lemon, newly expressed, for about half an hour; these are then placed in gold solution for an hour, and afterwards placed in water, acidulated with acetic acid, for a week. As, however, it is possible to prepare a score of fragments taken off the animal at the same time, and placed in the same lemon juice, gold solution, and acidulated water, for the same periods, and under precisely the same conditions throughout, with the result of finding perhaps

¹ Abstract communicated to the Royal Society of Edinburgh, Jan. 7, 1884.

one fragment successful and all the others worthless; so, in order to obtain a chance of success, I prepare a very large number of fragments, taken from the animal at periods varying from one to ten hours after death, using solutions of gold, both pure and in combination with sodium or potassium, taking the $\frac{1}{2}$ per cent. solution as a standard, but varying this in different saucers, and varying also the time of exposure to gold from twenty minutes to three hours; in short, varying the conditions as much as possible. All this naturally increases the labour of inspecting the sections after they have been cut a thousand-fold, but an experienced investigator considers himself well repaid for it all if he obtains a very small modicum of success.

The forms I am about to describe are three in number, and the first difficulty I experience is to find names for them. In the first place, new names have been multiplied to a most unwarrantable extent whenever the slightest peculiarity in shape or position has shown itself in an already named organ. In proof of this, that veteran investigator of nerve terminations, W. Krause, in the exhaustive article he published in the *Archiv für Mikroskopische Anatomie* for 1881, enumerates no less than ten names which have been applied in Germany to what is clearly one structure, the Vater body, or, as we call it in this country, the Pacinian body. In this I am wholly at one with him, in spite of Professor Merkel's subsequent protest. In the second place, I cannot too strongly condemn the practice of attaching names implying special physiological functions to structures which may subsequently be shown to have no such function as their names imply. Witness the touch corpuscles of Meissner or the touch cells of Merkel, neither of which have probably any connection with the sense of touch. On this subject I may give my opinion both as regards the new forms I am about to describe and the already described forms of nerve terminations. When I compare the materials I have collected for a comparative study of nerve termination in the Mammalia with the materials already published by various investigators, I believe I may claim to have gone as far into the question as any of them. All that I have seen and studied, however, up to the present moment, justifies me in expressing the opinion that our knowledge is not yet sufficient to warrant us in attaching

any special function to any special nerve terminal organ, the forked endings on the hair follicles *perhaps* excepted, which are *probably* tactile. In fact, we have no right to assume that the sensations which physiologists have specialised, such as the sensations of touch, temperature, moisture, weight, &c., have any equivalent representatives in anatomical structures. Surrounding conditions and not physiological requirements may have led to differentiation in form. As I have elsewhere shown, they have led to the formation of the so-called touch organ (organ of Eimer) on the snout of the Mole, and to the formation of intra-epidermic nerve fibrils in general. Taking all the preceding circumstances into consideration, I deem it necessary, for convenience in description, to apply distinctive names to the three forms I am about to describe, which, while they have no special meaning anatomically, will prevent others from applying an erroneous physiological nomenclature to them. The first form I shall call the *Browne* bodies (figs. 1-12), in honour of the lady through whose munificence the biological post I now occupy has been founded, and of which this research is the first fruits. The second form I shall name the *Hoggan* bodies (figs. 15-22), in honour of my ever-helpful co-worker and wife, without whose aid I should have done nothing in biological research; and the third form I shall call the *Blackwell* body (figs. 23-25), in honour of our venerable colleague and friend, Dr Elizabeth Blackwell, the first Englishwoman to obtain a medical degree and to be placed upon the medical register, and who still lives as the brightest ornament of her class.

Those who have studied any of the researches I have already published on nerve terminations, as, for example, those published during the past year in the *Journal of the Linnean Society*, vol. xvi. p. 546, or in the *Journal de l'Anatomie*, &c., p. 327, will understand that my descriptions will be directed, not to proving these new forms to be altogether distinct from existing forms, but, on the contrary, to proving that they are closely allied to them. A strong believer in evolution of different elements from one original type, I seek only to add links to the chain, which, when completed, will give us a conception of the original form as it first came from the hands of the Creator.

The already known cutaneous nerve terminal forms or elements,

which I shall have to find a suitable place for the three new forms, may be shortly enumerated as follows:—1. Non-medullated nerve fibres, existing everywhere at the periphery of the nervous system, and forming in the skin the subepidermic plexus of nerves (*n*, figs. 1, 3, 5, and 6) distributed to the blood-vessels, *v*. Of this plexus the intraepidermic nerve fibres are occasional off-shoots, due to mechanical rupture and entanglement amongst the epidermic cells (figs. 13, 14, and 26).

2. The so-called touch corpuscles or Meissner bodies (figs 13, 14, and 26), as they exist only in the palms and soles of man, monkeys, and marsupials. These are essentially composed of nerve cells aggregated together in a mass or ganglion, being connected to each other by non-medullated nerve fibrils, and to the great nerve centres by medullated nerve fibres.

3. The forked nerve endings (fig. 29) found on the follicles of ordinary hairs, and to a comparatively smaller extent on feelers or whisker hairs.

4. The Pacinian bodies (*P*, fig. 28), combining under that name all the variously-named bodies enumerated by Krause, all of which are characterised as possessing one main axial nerve fibre surrounded by a larger or smaller number of laminar envelopes or capsules.

5. The segregated nerve cells (figs. 27 and 28) lying on the lower stratum of epidermic cells, generally separated from each other by one or more of the epidermic cells, amongst which they are placed as a peripheral ganglion of nerve cells, of which the nerve cells placed on the follicles of feeler hairs, or underneath the epidermis on specially sensitive portions of the surface of the skin, are notable examples.

These five forms (genital nerve endings excluded) may be held to typify all that is yet known of cutaneous nerve terminations in mammals. Other forms have, indeed, been figured in the published researches of the latest and best of investigators, more especially of those who have not made use of the gold method of preparation; but they are, as I shall subsequently show in a projected series of researches, the result of misinterpretations. Often a small nerve bundle, containing half a dozen or so of fibres, has been cut transversely at the point where one of its fibres leaves the bundle at right angles to it. Here one sees a circular or ap-

parently globular body, in which one fibre appears to terminate, and it is at once described as a touch body. Such mistakes abound, and are readily accepted as correct. A typical example of this is afforded by Longworth, in his article on the termination of the nerves in the conjunctivæ, amongst which the object in question passes as a touch body. In Merkel's excellent monograph on nerve terminations we have also many mistaken forms; such, for example, as the representation of the touch-body of the mole, which has not only no existence in fact, but the actual representative of a so-called touch-body in the mole (fig. 28) has not the slightest resemblance to the spurious one.

From these remarks it will be understood that the five types I have given comprehend all previously recognised forms, and I shall endeavour now to make a preliminary distribution of the new forms amongst the old. The Browne body stands midway between the non-medullated nerve fibres more immediately in connection with a medullated nerve, on the one hand, and a forked ending of a nerve on the follicle of an ordinary hair on the other. The Hoggan body stands midway between the forked ending on a hair follicle (fig. 29) on the one hand, and a Pacinian body on the other. The Blackwell body (figs. 23, 24, and 26) stands midway between the segregated cells of the sub-epidermic nerve ganglion (fig. 27) on the one hand, and the Meissner body (fig. 26) in its young stage, on the other.

Another point of interest is whether the habits of the animal have had any effect on the development or peculiar conformation of the nerve endings, or if there be any anatomical reason for its having those habits. Anyone observing the habits of the raccoons in a menagerie must have noticed that the paws of these animals are constantly wet through continually dabbling in the water supplied to them. Strange to say in none of my sections have I been able to detect a sweat gland. This may not mean much, considering that the fragments of tissue show only the upper portion of the dermis attached to the epidermis, as necessitated by the gold process of preparation, and a more extended examination afterwards may show plenty of sweat glands. But I have otherwise noticed that in many animals, and especially in the rodents, the nerve endings equivalent to the Browne and Hoggan bodies are only found in the immediate

vicinity of the openings of sweat glands, which in comparative size may be well styled enormous. That the nerve endings bear some relationship to those enormous sweat glands there can be no manner of doubt, and the comparative, if not entire, want of these glands in the vicinity of the nerve endings in the raccoon is at all events suggestive. That the presence of moisture modifies in some way the function of the nerve terminations is seen in the immense venous sinuses lying close to the taste bulbs, as remarked by Ranvier, and the presence of the enormous sweat glands in connection with tactile or other sensation would point out to similar necessities. It may therefore be yet discovered that it is to the absence of such moist conditions that the washing habits of the animal are due, and that, secondarily, these habits may have caused modification in the form of the nerve terminations to occur, such as I have chronicled.

I. *The Browne Body or Termination.*

The homologies of this form of nerve termination are somewhat difficult to trace. Found in or near the apices of the dermic papillæ, it appears to occupy the position of the Meissner body, but there the resemblance between the two seems to end.

While the latter is developed from, or consists primarily of, nerve cells, which are very evident in early life (fig. 26), the former, at all events in the adult specimen I have examined, showed no such structure, although, of course, like every other form of nerve termination, it has its origin in special cells. It rather appears to me to have developed secondarily, if I may so speak, from the plexus of non-medullated nerves lying immediately underneath the epidermis, from which, as I have shown elsewhere, the intraepidermic nerve fibrils are merely mechanically severed offshoots, broken off perhaps by the same process which conduces to the formation of the bodies now under consideration. If, indeed, we could imagine a medullated nerve proceeding to that plexus, and immediately beyond the point at which it has joined it, and its axis cylinder divided into two or three fibres, to have become ruptured, and the portions of these ruptured fibres to have retracted upon themselves, so as to form a more or less irregular fork consisting of two or three prongs, we should thereby obtain a conception of these terminations,

not only morphologically correct but probably also correct as a question of development. As a matter of fact, I have clearly shown elsewhere¹ that—1st, Such ruptures of the subepidermic plexus are continually taking place; and 2nd, That even the grosser axis cylinder, when it ruptures, retracts upon itself,² becoming much thicker and showing a tendency to become more or less spiral.

In such a termination we have a medullated nerve preserving its medullary sheath until it has passed within the papilla; then ensues a naked portion of the axis cylinder, terminating in a bi- or tri- furcation into the terminal fork, as shown in A, fig. 1. When that fork lies close to the apex of the papilla, we find the prongs bent at right angles to the main fibre, whether by pressure or by original position at the time of the rupture it is difficult to say. At other times, when nearer the base of the papilla, the forks pass perfectly straight in the axis of the line of the main fibre, and in this condition they resemble the forked termination on the follicles of the ordinary hairs of the body (A, fig. 2). This brings us at once to an interesting question of homology, and those who have read in the articles already referred to my first conceptions and my subsequent endeavours to trace a homology between the forked terminations on ordinary hair follicles and Pacinian bodies, or even the Meissner bodies, will at once perceive the value of the present factor in that question. Agreeably also with the foregoing, it will be remembered by those who, at the last meeting of the British Medical Association in Liverpool, took part in the proceedings of the Anatomy and Physiology Section, that I exhibited, under the microscope, specimens of such forked terminations in course of development on hairs, and I explained that these appeared in their earliest forms to be portions of the subepidermic plexus of non-medullated nerves, which become ruptured, and afterwards retracted to what in fully developed forked terminations are the peripheral terminations of the forks. This conclusion, arrived at independently on forked endings, receives additional force from, as well as gives particular emphasis to,

¹ *Journal de l'Anatomie*, 1883.

² "De la Degeneration et de la Régénération du Cylindre-axe," in *Journal de l'Anatomie*, 1882.

what I have stated as probably occurring in the Browne bodies.

In fig. 5 we see two contiguous papillæ, in one of which (B) the medullated nerve is seen in continuation with the non-medullated nerves passing along the blood-vessels; while in the other (A) the rupture appears to have occurred, and forms a very small specimen of the Browne body. In figs. 2 and 3 we also see what is evidently a very large portion of the fibres of the plexus, which have retracted and become consequently thicker, taking, however, exceptionally divergent positions, as if originally the rupture had occurred while they lay alongside of the blood-vessels of the papilla.

It is essential that I should lay great stress on the fact that in such early and typical forms of the Browne body as are shown in figs. 3, 5 A, 6 B, 7, &c., *there is no vestige whatever of a capsule surrounding them, and the terminations do not appear to be embedded in a granular matrix.* These appear to me to be the only features which distinguish them from the next form, which I have called the Hoggan bodies, of which I believe the Browne bodies are, morphologically at least, only an earlier form, there being many transition forms between them, which I have failed, in spite of the employment of every technical device I possess, to range definitely in either category. These transition forms, like figs. 4 A, 6 A, 12, &c., might be described as Browne bodies, without distinct laminar envelopes or capsules, but embedded in a granular matrix, on the one hand, or Hoggan bodies, without capsules, on the other. In connection with this, however, I have remarked little groups of cells, identical in their appearance with the cells which form the capsules of the Hoggan bodies, and lying close to typical Browne bodies (see fig. 7), which can be very clearly seen to be destitute of any envelopes. The question may very fairly be put whether, granting that these bear some relation to the nerve terminations, they may not have been stripped off from what was once a Hoggan body, instead of going to form one by enveloping the Browne body in a capsule. All analogy, however, seems to me to be against the former and in favour of the latter hypothesis, for I have noted elsewhere, first in the case of the mole, and extended it afterwards upon a very large series of animals, that when the Pacinian bodies are

close to the epidermis, they may even appear to be without a single capsule, and that the deeper they lie from the epidermis within the dermis or hypodermis, in the one animal or in the series of animals, the larger the number of the laminar envelopes they acquire, and the more enormous in size do the Pacinian bodies become. In this respect the feet of the mole and the cat represent the extreme points in the scale of development. While, however, there appears to be little analogy, except in position, between the Meissner body and the Browne body, it ought to be borne in mind that, in advanced age, when the cellular structure of the Meissner body is no longer recognisable—as, for example, in man, monkeys, and marsupials—and the chloride of gold only shows the direct path of fibres within the Meissner body as a dark or black arborisation, there is at that period a great similarity in appearance between the two. This can be recognised at once on comparing the Browne body shown in fig. 10 with the Meissner body from a man aged 56 shown in fig. 13, and from an old kangaroo in fig. 14.

In the more typical of the Browne bodies, not only is it impossible to detect either an enveloping cellular capsule or a granular matrix different from the ordinary gelatinous matrix of the skin, but the very form of the termination and the opposite direction in which they lie to each other (fig. 3 and B fig. 2) preclude the possibility of their being surrounded by or enclosed within a capsule. At other times we may have two, or even more, medullated nerves passing to the same Browne body (fig. 4, A), where the forked endings or arborisations entwine with each other in a manner which shows that they form the one body, just as two or more medullated nerves are often seen in connection with the same Meissner body, but as they are never seen to be with one and the same Pacinian body. On the other hand, careful examination of that same figure shows the beginning of the formation of a cellular capsule, so that I find it difficult to range it under either of the two forms, and I only class it amongst the Browne bodies, because I have never known two medullated fibres to pass to a body distinctly of the type of the Pacinian body in general or of the Hoggan body in particular. In connection with the formation of the Browne bodies, I call attention to the peculiar nodulated or moniliform appearance of

the non-medullated nerves (*n*) seen in figs. 5 and 6. This appearance, although almost constant in *intraepidermic* nerve fibrils, due, I should suppose, to pressure of the epidermic cells upon the nerve fibrils passing amongst them, is rarely seen in such fibrils while lying within the dermis.

II. *The Hoggan Body.*

The essential point in the definition of this body is that it may have two, three, or even more fibres, resulting from a division of the original axis cylinder immediately after its entrance within the capsular envelopes. In all the forms of the Vater or Pacinian body yet known to exist in the Mammalia, there is no evidence of more than one axial fibre. W. Krause, indeed, shows an example from a goose, where the fibre bifurcates immediately after passing within the capsules, but even that example appears to be exceptional. Key and Retzius also, in their admirable monograph on the subject, show a large number of examples of Pacinian bodies, which, at the peripheral extremity of the one invariable axial fibre, break up into numerous arborisations; but they show no example of a nerve bifurcating immediately after it has passed within the capsules. The same may be said of the published observations of Merkel. In short, it may be stated that, as far as my knowledge goes, nothing hitherto has been observed similar to the termination of the nerve within the Hoggan body.

The manner in which this bifurcation takes place is seldom the same in any two cases. At one time it may take place immediately after the nerve has passed within the capsule, and result in the formation of two fibres nearly equal in size, which run parallel to each other in the substance of the Hoggan body, as in figs. 19 and 20. Instead of running parallel, they may become twisted round each other, as in fig. 18, or they may each of them form arborisations along their course, as in fig. 17. Quite as frequently we may have three or more fibres coming off at different points in the interior of the body, forming what might be called a stag's horn variety of termination, as in figs. 15 and 16, and of which I have seen even better specimens after these latter had been drawn for publication. In other cases only one axial fibre is seen, thus forming a close link with

the ordinary form of Pacinian body, as in fig. 21. This form is, however, not so conclusive as the others, for it may well be conceived that if a two or three pronged forked termination within the body be seen edgewise, it will appear as if there was only one axial fibre, and the same would be true if a longitudinal section were made through the centre of a Hoggan body, for it would probably cut off one or more of the terminal branchings; as indeed appears to have taken place in fig. 21, where also the dissecting-needle has torn off and otherwise disturbed the capsule. Transverse sections, like fig. 22, show even more clearly the relations of the double or triple fibres to each other, and to the axis of the Hoggan body.

It is unnecessary that I should lengthen out this paper by repeating what I have said, under the heading of the Browne body, on the relationship of that body with the Hoggan body. It is seldom placed so high up in the papilla as the Browne body, being either found in its lower part, or below the level of the deepest projection downward of the epidermis into the dermis; and the deeper its level in the dermis, the more numerous are the capsular envelopes which surround it. Generally the nerve upon which the body is placed loses its medulla before it reaches the body, and that medullated nerve generally has two, if not three, membranous sheaths around it near to the point where it joins the body. Although in most cases the axis of the body is the same as that of the nerve leading to it, yet, in certain cases, when within the papilla, the long axis of the Hoggan body gets bent to a right angle with that of the nerve. In either case, there is a very close resemblance in the nerve termination to the forked terminations of the nerves upon the follicles of ordinary hairs. I, indeed, consider that there is complete homology and analogy between them; and, so far, I claim to have arrived successfully at my long-worked-for aim of showing the forked endings to be homologous with the Pacinian bodies through the intermediary of the Hoggan bodies.

III. *The Blackwell Body.*

When one sees some examples of this body (fig. 25), there is difficulty in deciding whether in its homology it is more allied to

the subepidermic nerve ganglia or to the Meissner body, but after examining a large number of specimens, I am clear that it is with the subepidermic ganglia that it is most intimately connected. Fig. 24 is a first link in that direction, fig. 23 is a second link, where, moreover, an intraepidermic nerve fibril is seen to connect the peripheral ends of two cells together while they lie within the epidermis, a feature which, in its exaggerated forms, enabled me to destroy Professor Merkel's theory of separate functions for the so-called tactile cells and for the intraepidermic nerve fibrils. I showed that (fig. 27), although hitherto unnoticed by any investigator, the cells and the fibrils were often found continuous with each other, belonged therefore to the same system, and could not consequently possess separate physiological functions, such as touch and temperature, as he had suggested. The presence of the little twig *i* connects therefore the Blackwell body homologically with the subepidermic ganglia, and of course equally with the non-medullated fibres of the subepidermic plexus.

On the other hand, it is extremely rare, speaking of the mammalian animal forms in general, to find medullated nerves in connection with such ganglia. This is found frequently enough in the pig; but it is exceedingly rare in the horse, where, moreover, several non-medullated fibres pass centrally from the ganglia. This is comprehensible where the cells are much scattered within the epidermis, as is shown in several of the figures illustrating the published researches I have before alluded to. In no other animal have I as yet seen the nerve cells so compressed together, and forming so distinct a body as is shown in figs. 23, 24, and 25, and no other observer has recorded anything of the kind, to my knowledge. In its simplest form, and in very young animals, where the ganglion may afterwards assume a more complex form, the nerve cells are scattered widely apart, as seen in the nose of a young kitten or in the great ant-eater when adult. As growth advances, and the papillæ become accentuated, the nerve cells become specially congregated near the base of the interpapillary down-growth, as seen in the nose of the old cat (fig. 27), or in the pig and horse.

In the feet of the mole, the nerve cells, varying from two to four in number in young adults, but ranging to above a dozen

in very old moles, become enclosed within the apex or point of a down-growth of the epidermis, but, as far as I have yet been able to detect in some thousands of examples, no medullated nerves are ever seen in direct connection with these cells in the mole, although, in connection with these cell groups, one or two small Pacinian bodies (fig. 28) are generally found, which are invariably attached to medullated nerves.

The very large size of the nerves attached to the Blackwell bodies, and the large number of cells compressed together, each cell of the group being apparently connected by a separate fibril to the axis cylinder of the one great medullated nerve, appear to lend some force to the theory that each axis cylinder is composed of a large number of minute fibrils, as a submarine telegraph cable possesses a core or axis cylinder composed of several copper wires. At all events, that is the only reason I can conceive for one comparatively so large a medullated nerve passing to each body.

Again, a careful examination of some of the more pronounced forms (fig. 25) gives one the impression that these bodies are semi-detached from the epidermis; are, in short, in a line of development which, in process of time, will end in their becoming wholly detached from the epidermis, and that then there will be no distinction to be drawn between them and the more simple forms of the Meissner bodies, as they are found, for example, in marsupials. All the foregoing considerations seem to warrant me in holding that the Blackwell bodies stand midway between the subepidermic nerve ganglia and the detached Meissner bodies, linking these two structures together in the same homological chain.

CONCLUSIONS.

1. The Browne body in the raccoon appears to be homologous with the forked nerve termination on follicles of ordinary hairs, and occupies a position in development between the subepidermic plexus of non-medullated nerves, on the one hand, and the Hoggan body, on the other.

2. The Hoggan body resembles, in its external envelopes, a Pacinian body; internally, it appears to be homologous with

the forked nerve termination on follicles of ordinary hairs. It stands midway between the Browne body, on the one hand, and the Vater or Pacinian body, on the other.

3. The Blackwell body stands midway between the Meissner body, on the one hand, and the subepidermic ganglia of nerve cells, on the other. Like the latter, it is intimately connected with the intraepidermic nerve fibrils, which may be demonstrated in connection with the nerve cells which essentially form the Blackwell body. The cells are in direct connection with one large medullated nerve.

DESCRIPTION OF FIGURES IN PLATES VIII. & IX.

Drawings made with the camera lucida under the $\frac{1}{12}$ oil immersion object glass of Zeiss, afterwards reduced by photography to a magnitude of $\frac{1}{300}$ diameters. Figs. 1 to 12 show Browne bodies; figs. 15 to 22 are Hoggan bodies; figs. 23 to 25 are drawings of Blackwell bodies.

In all the figures the following letters apply equally throughout:—*c*, cells; *d*, dermis; *e*, epidermis; *ce*, capsular envelopes; *f*, forked endings; *h*, sheath of Henle, generally double on the medullated nerves; *i*, intraepidermic nerve fibrils; *m*, medullated nerves; *n*, non-medullated nerves; *p*, papilla.

Fig. 1. Browne bodies from the raccoon. At *A* the three prongs forming the termination lie quite straight, and, except for their nodulated appearance, are in every way similar to the forked nerve terminations on hair follicles shown in fig. 29. In *B* the forked terminations are much more complex and contorted.

Fig. 2. Browne termination. At *B* the forked endings lie along the blood-vessels, as if they had previously formed part of the non-medullated nerve plexus supplied to the blood-vessels, and after rupture had retracted into their present form and position. At *A* the nerve ending appears to be assuming the condition of a Hoggan body.

Fig. 3. Browne termination, showing great divergence in the terminal forks, and like *B* (fig. 2), it not only possesses no capsule, but, from the divergent forks, it would be difficult to conceive of their being surrounded by capsular envelopes.

Fig. 4. In this figure we have one medullated nerve dividing into two medullated fibres, each of which terminates in a forked ending. The forked endings of both intertwine so as to constitute a double Browne termination (*A*), around which a capsule is about to be formed, as if to convert it into a Hoggan body. At *B* a very distinct three-pronged termination is seen within three distinct capsules, constituting a typical Hoggan body.

Fig. 5. Illustration of the manner in which I believe the Browne terminations are formed from the subepidermic plexus of non-medullated nerves upon the blood-vessels. At B a medullated nerve is seen joining the plexus, while at A the rupture seems to have lately occurred, judging from the small size of the Browne termination seen there.

Fig. 6. In this figure A seems to be a transition form to a Hoggan body. At B there is a Browne body almost similar to A (fig. 7). Particular attention is called to the nodulated condition of the non-medullated nerves *n*, in figs. 5 and 6.

Fig. 7. Two very distinct Browne bodies in contiguous papillæ. Although these bodies can be very distinctly seen in the preparation to have no capsule, the cells *c* lying beneath each appear as if passing to envelope the termination.

Fig. 8. Very complex Browne body, in which cells appear both above and below the terminations.

Fig. 9. Browne body seen from *above* in a horizontal section of the skin.

Fig. 10. Browne body seen from *below*. The medullated nerve shown in perspective is six times longer than it appears in the drawing.

Fig. 11. Browne body seen from above.

Fig. 12. This appears to be a Browne body lying against a group of cells, but it might almost be considered a Hoggan body from the regularity of arrangement in the cells.

Fig. 13. Meissner body from the sole of the foot of a man 56 years of age, as seen from *below*, for comparison with the Browne body seen also from below in fig. 10. In old age the cellular structure of the Meissner body becomes obscured, and only the nerve fibre or direct path of the nerve influence is blackened by the gold solution. The cellular structure of these bodies in early life is illustrated in fig. 26.

Fig. 14. Meissner bodies from the kangaroo (Bennett's wallaby), for comparison with the Browne bodies.

Figs. 15 and 16. Hoggan bodies with three branches and very distinct capsular envelopes.

Fig. 17. Hoggan body, with two branches, both of which terminate in arborisations.

Fig. 18. Hoggan body with two terminal branches, which have become twisted on each other.

Fig. 19. Hoggan body possessing a larger number than usual of laminar envelopes. In this and fig. 18 the knife has passed through the body, so as to cut away the nerve attached to it.

Fig. 20. A Hoggan body, which, by pressure from above or below, is becoming bent at right angles to its nerve.

Fig. 21. Section through a Hoggan body with only one axial fibre, a type which connects the Hoggan bodies with the Pacinian bodies.

Fig. 22. Hoggan body seen in transverse section and containing two central fibres.

Fig. 23. Blackwell body, consisting of a large number of nerve cells within the epidermis, and connected with one very large medul-

lated nerve. This example resembles a subepidermic nerve ganglion. Two of the cells are seen to be connected with each other peripherally by an intraepidermic nerve fibril, the third branch of which passes up through the epidermis.

Fig. 24. Blackwell body in which the cells are more compressed together than in fig. 23, and having no admixture of epidermic cells, now constitute a distinct body.

Fig. 25. Blackwell body globular in shape, which, although partially attached to the epidermis, resembles closely a Meissner body in its early stage of formation. Compare this with the next figure.

Fig. 26. Excessively thin transverse section across a Meissner body from the palm of a young Weeper Capuchin monkey, showing the cellular structure of the Meissner body in its early stage of formation, during which it resembles the most highly developed stage of a Blackwell body. Compare this with fig. 13, a Meissner body in old age.

Fig. 27. Subepidermic ganglion of nerve cells on an interpapillary down-growth of the epidermis, from the nose of the cat. It is inserted here to establish homology with the Blackwell bodies, which it resembles, except in that the nerve cells are separated from each other by epidermic cells.

Fig. 28. View from below of the group of nerve cells which are collected in one mass on an epidermic down-growth on the foot of a very old mole. They are always accompanied by two or three small Pacinian bodies *p*, but are seldom, if ever, attached to medullated nerves, as in the Blackwell bodies.

Fig. 29. Three forked nerve endings, from the follicle of an ordinary hair on the snout of the raccoon, for comparison with both the Browne and Hoggan bodies, which both seem to be homologous, and probably analogous, with the forked ending on the hairs.

THE FOLD OF THE NATES. By J. SYMINGTON, M.B.,
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Edinburgh. (PLATE X.)

THE "fold of the nates," or the "gluteal fold," is stated in almost all the text-books on anatomy to correspond to, or to be formed by, the lower border of the gluteus maximus, and in no English work with which I am acquainted are these assertions disputed. Thus Holden, in his *Landmarks, Medical and Surgical*, third edition, 1881, says:—"The deep furrow, termed the fold of the buttock, which separates the nates from the back of the thigh, corresponds with the lower border of the gluteus maximus."

In Quain's *Elements of Anatomy*, ninth edition, 1882, vol. i. page 233, the lower border of the muscle is said to "lie in the fold of the nates," and at page 690, under the section devoted to superficial and topographical anatomy, it is stated that "the region of the hip, gluteal region or buttock, extends from the subcutaneous iliac crest and the origin of the gluteus maximus above, to the fold of the nates, produced by the thick lower margin of the gluteus maximus, below."

It is quite unnecessary to quote from further authorities, but I may mention that statements practically identical with those of Holden or Quain will be found in the works of Ellis, Gray, Heath, Wilson, Chiene, Allen, Treves, Reeves, and in Todd's *Cyclopædia of Anatomy and Physiology*.

With reference to foreign authors I can find no allusion to the subject in Sappey's *Traité d'Anatomie*. In Cruveilhier's *Traité d'Anatomie*, fifth edition, 1877, the lower border of the muscle is said to form a very marked prominence. From the context it is evident that the prominence he refers to is the upper boundary of the gluteal fold, as he points out its surgical importance in connection with the diagnoses of disease of the hip-joint, &c. Tillaux in his *Traité d'Anatomie Topographique*, troisième édition, 1882, says:—"It is the inferior border of the muscle (gluteus maximus) which determines the formation of the gluteal fold, and consequently the fold moves up and down with that muscle."

Heule, in his *Handbuch*, states that its lower border corresponds pretty accurately to the transverse fissure which separates the gluteal region from the back of the thigh. In Roser's *Surgical Anatomy*, translated by Galton, the relation between the two is still more sharply defined. He says—"The boundary between the nates and the back of the thigh is marked by the gluteal fold, which lies parallel with the edge of the gluteus, and is a guide to the position of the margin of the muscle."

A different, and I believe more accurate, account of the gluteal fold will be found in Luschka's *Anatomie des Menschlichen Beckens*, 1864. In giving the boundaries of the gluteal region (page 32), he points out that its inferior one—the gluteal fold—does not correspond, as he states it is erroneously asserted to do, with the lower border of the gluteus maximus, but passes from the inner circumference of the ischial tuberosity outwards, in a curved line, towards the great trochanter. He appears to consider the fold to be due to a pad of fat, and bands of connective tissue which pass from the skin through the fat to the ischial tuberosity and fascia lata. On page 138 he has a woodcut, in which he represents a view of the buttocks. On the one side a dissection of the gluteus maximus and upper part of hamstrings is seen, on the other side no dissection has been made, but the prominence of the nates and the situation of the gluteal fold are indicated. It shows the difference in position and direction of the gluteal fold as compared with the lower border of the gluteus maximus. I have not seen a reference to Luschka's views in any work, yet the incorrectness of the usual statements can easily be demonstrated. I have taught views practically similar to those of Luschka for the last three years, although it was only recently, in looking up the literature of the subject, that I read his description.

The lower border of the gluteus maximus passes from the coccyx downwards and outwards to about the juncture of the upper with the middle third of the shaft of the femur. As it passes rather more downwards than outwards the border is more internal than inferior. Taking the lower border as straight, we found it formed an angle of about 145° with the mesial line of the trunk. The gluteal sulcus, on the other hand, passes outwards and slightly upwards. It is continuous internally with the groove between

the inner side of the thigh and the perineum, and extends outwards below the ischial tuberosity towards the lower part of the great trochanter. It usually reaches about half-way across the back of the thigh, and gradually disappears as it passes outwards; occasionally there are one or more transverse folds below it. Close to the middle line the gluteal sulcus will be found, in an average adult, three or four inches below the muscle; but, owing to the lower border of the muscle inclining downwards and outwards, while the gluteal fold extends transversely outwards, the two meet a little external to the middle of the lower border of the muscle, and then the fold passes on to the posterior surface of the muscle. The outer end of the lower border of the muscle reaches two or three inches lower down than the outer end of the gluteal fold. As it is usually the custom in the dissecting room to first place the body in the lithotomy position and dissect the perineum, the normal relations of the fold are apt to be destroyed before the gluteal region is dissected. One of the best methods of showing the relation between the two is that which I have adopted in Plate X.

In this case I carefully fixed the skin in the position of the gluteal fold with several long pins, and then exposed the gluteus maximus, except where the gluteal fold crossed it. The subject was a well-developed adult female. I have followed this plan in several bodies, both male and female, with practically identical results, except that in a very muscular adult male the gluteal fold was found to cross on to the gluteus maximus a little nearer the middle line, and to extend across the muscle nearly at right angles to its fibres.

The want of correspondence between the two is also readily seen in sagittal sections through the gluteal region and upper part of thigh.

It is, however, by no means necessary to make dissections to prove this, as it can easily be demonstrated on the living body. In a moderately muscular man, with a limited amount of subcutaneous fat, the lower border of the gluteus maximus can be clearly made out, especially when the muscle is contracted. Through the kindness of my friend Dr F. Godfrey, senior house-surgeon with Professor Annandale, I had an opportunity of examining a young man in whom the lower border of the

muscle was readily traced. The inner part of the lower border of the muscle, which forms the posterior boundary of the ischio-rectal fossa, bulges inwards when the muscle contracts, and by the simultaneous action of the two glutei the two nates are approximated, and the cleft between the coccyx and anus is deepened. This part of the muscle is, in fact, closely related to the posterior part of the natal cleft. The border of the muscle can be traced outwards over the ischial tuberosity, and under the gluteal fold. The portion of the lower border, which extends from the level of the gluteal fold downwards and outwards to the femur can be felt, and in favourable subjects seen, in the contracted condition of the muscle. If a person standing erect contract his gluteus maximus the fold becomes a little more evident, but is not much affected. If he flex one limb, and support himself mainly upon the other, the fold on the flexed limb becomes less evident, lower than the other, and inclined downwards and outwards. The fold on the other side becomes more marked. The fold gradually disappears in the progress of flexion, and when the thigh is at about a right angle with the trunk it is no longer visible.

With regard to the causes of the gluteal fold the usual idea that it is formed by the gluteus maximus is a natural deduction from the belief that the gluteal fold corresponds to the lower border of the muscle. I trust I have proved this to be erroneous, and I think an examination of the two will show that the gluteal fold is essentially independent of the gluteus maximus. This anatomical error has often led surgeons to attribute the tendency to disappearance of the fold in hip-disease to atrophy of the gluteus maximus, but, I believe, the majority of surgeons more correctly regard the changes in the fold to be dependent upon the flexed position of the limb. I have found the gluteal fold well marked in cases of great emaciation and general atrophy of the muscles of the body. Thus, it was well defined in a man aged 37, 5 feet 6 inches in height, suffering from advanced pulmonary phthisis, who weighed only 6 stone 4 lbs. Although the fold varies in these cases, yet it certainly has no definite relation to the degree of development of the gluteus maximus.

The causes given by Luschka, to which I have already referred, are undoubtedly important factors in its production;

but there are one or two others which assist in its production. The prominence of the lower and inner part of the nates is largely due to the ischial tuberosity, and the fold is always best marked where it passes outwards below it. The amount of flexion which can occur at the hip-joint with the knee flexed, and slight pressure exerted upon it with the hand, equals 145° to 150° (Morris). It is obvious that the skin which is put upon the stretch in flexion of the thigh is relaxed in the extended condition, and thus a fold naturally tends to occur below the projecting ischial tuberosity.

RESEARCHES INTO THE HISTOLOGY OF THE CENTRAL GREY SUBSTANCE OF THE SPINAL CORD AND MEDULLA OBLONGATA. By W. AINSLIE HOLLIS, M.D. Cantab., *Brighton*. Part III. (PLATE XI.)

(Continued from page 65.)

Goll's Tract, or the Postero-median Column in the Medulla (continued from page 64).—An antero-posterior longitudinal section of the medulla passing through one of Goll's columns (fig. 1, *g*, *G*) shows well the terminal nucleus of these columns. The column just below the calamus suddenly enlarges and forms an oval ganglion (*clava* or *nucleus gracilis* or *posterior pyramidal ganglion* of authors). As seen in longitudinal section, with its long axis parallel to that of the cord, the clava has somewhat the appearance of a knob at the end of a walking-stick. Within its central grey ganglion the synectic tissue assumes the shape of convoluted thread-like strands, containing many (mostly pyriform) nerve cells.

If a section of the medulla is made in a plane parallel to the preceding one, but somewhat external to it, so as to include the cervix of the posterior cornu, its medullary prolongation and the cuneate or restiform nucleus (fig. 2, *p*, *C*), we shall find that the latter nucleus terminates the posterior column of grey substance in a similar manner as a knob-like extremity, adjacent to and just below the nucleus gracilis. In internal structure these two ganglionic bodies closely resemble each other. In such a section of the medulla as the one I have just described, there are, consequently on a level with the lower border of the olivary body, three great nuclei observable, two posterior—terminating longitudinal rachidian tracts of grey synectic tissue—and one anterior (the olivary nucleus) dissociated from direct communication with any spinal segment (fig. 2, *G*, *C*, *ol*).

In so describing the structure of these nuclei and their situation, as regards the central grey substance, I must disclaim any wish to assume that their functions are necessarily closely asso-

ciated with those of the grey tracts they terminate, as any such inferences might not only be premature, but they would necessarily lead to questions beyond the scope of the present paper.

The Dendroidal¹ Fasciculus.—To describe clearly the formation of this synectic fasciculus in the central grey substance I must return shortly to the consideration of the grey investing tissue of the medullary canal as it passes obliquely backwards in its course to the fourth ventricle. If a series of antero-posterior longitudinal sections are made through the medulla similar to those before described, and examined severally from within outwards, the first sections just external to the canal will be diagonally bisected by a grey streak of synectic tissue, having for its posterior boundary an oblique line; anteriorly this central column has a frayed-out lunated edge, whence proceed numerous delicate ramuli of synectic tissue towards the anterior border of the medulla. At the lower part these ramuli pass directly forwards. At a higher level their direction (in man) is forwards and upwards (fig. 1, *d*). Near the slender nucleus (fig. 1, *G*) they pass horizontally forwards, crossing the vesicular synectic investment of the canal at this point. Indeed these bands are apparently the only connecting links between the two grey columns. Other strands of synectic tissue in their course upwards pass round the lower border of the olivary body, and separate the bundles of white fibres composing the pyramid (fig. 1, *d*).

A section of the medulla in a plane parallel and external to the preceding (fig. 2) exhibits the histological peculiarities of the dendroidal fasciculus. This delicate fringe of synectic tissue commences about the level of the uppermost cervical vertebra as an interlacement of grey synectic tissue in the posterior column (that is the medullary extension of Clarke's column) and it expands rapidly as it ascends towards the anterior vesicular column (fig. 4). On a level with the point of decussation of the lowest pyramidal bundles slender branched fibres arise from the

¹ Δένδρον, ἔϊδος. From its branched appearance. At its lower border this fasciculus may be likened to an interlacement of branches, as seen in a thick leafless underwood. Higher, where its ramuli pass through a rift in the anterior column, it resembles the branches of trees violently blown by the wind.

inner aspect of the anterior cornu, pass upwards for a short distance, and then, bending obliquely forwards and upwards, divide the anterior grey column into two parts. Other fibres, springing from the lower truncated extremity of the same column, join the branches just mentioned in passing forwards and upwards through the columnar gap above described.

The direction of these fibres, passing, as they do, obliquely forwards and upwards, corresponds for the most part with that of the inner fibres of the fasciculus; and they, moreover, pass, as do the latter, although to a less extent, around the lower border of the olive. Above the extremity of the divided anterior column, the synectic branches arise partly from the posterior grey column and partly from its terminal nucleus (*n. cuneatus*), and the general direction of the uppermost is horizontally forwards. Along the edge of the cuneate nucleus these fibrous branches, as the stroma of the *fibræ arcuatæ*, cross the space between that nucleus and the olivary body.

In the young infant these grey synectic fibres of the medulla oblongata are relatively thicker than in the adult (fig. 5, *c*). The whole fasciculus seems to contain a larger proportional quantity of synectic tissue than it does at a later period of life (fig. 5, *d*).

Passing still further outwards in the series of parallel sections I am describing, the structure of the dendroidal fasciculus will be found to be much changed. In such a plane it becomes surrounded on all sides by the grey substance, above and below by the interlacement of the two lateral columns, behind and before by continuations of the posterior and anterior of these columns respectively (fig. 3, *d*). The white fibres in the centre of this fasciculus are here merely separated from each other in bundles by longitudinal strands of synectic tissue. The fibres forming the upper interlacement of the two grey columns above referred to still trend from the posterior column upwards and forwards to the prolongation of the anterior cornu. Just below the olive these two columns coalesce and together pass upwards as high as the calamus. Although they are thus united in one median column at this part of the medulla, they are still differentiated from one another to some extent. The anterior half of the column contains numerous multipolar and large pyriform cells (fig. 7, *c' c''*). On the other hand, the posterior

border is comparatively free from cellular elements. The grey substance is intersected by bundles of both longitudinal and transverse nerve fibres, and has a fenestrated appearance from this cause (figs. 2 and 3, *f*).

On the prolongation of the grey multipolar ganglion column of the anterior cornu into the medulla and its relations with the central multipolar vesicular column of that organ.—The cell-clusters at the extremities of the anterior cornu can be traced (as is well known) some considerable distance upwards through the medulla (see Plate VI., figs. 2, 3, 4). The caput (*processus lateralis* of some authors) of each anterior cornu is fairly well differentiated as high as the calamus occasionally. It usually ceases to be visible, however, as a cluster of multipolar cells some short distance below this point. Meynert considers this cluster of cells as representing the *processus lateralis* of the anterior cornu. The median nuclei of the hypoglossal nerves are supposed by the same authority to run continuously into the inner portions of the anterior cornua of the cord. I do not think that this is quite a correct interpretation of the relations existing between these ganglionic vesicular columns of the cord and medulla respectively. In longitudinal sections the anterior cornua of the cord can be traced upwards continuously as high as the olivary nucleus. Above this point, and where the two boundary columns of the dendroidal fascicle coalesce, the multipolar cells become more scattered, owing partly to the fenestrated formation of the synectic tissue at this point. About on a level with the centre of the cuneate nucleus, and on the inner (central) border of this conjoint column (fig. 1, *h*) there are the horizontal uniting strands of synectic tissue between the vesicular column I am describing and central canalicular investing column. These strands, I believe, are the only *vesicular* connecting links between these widely separated columns. It is, therefore, an error to say that "the median nuclei of the hypoglossal nerves . . . run undisturbed into the inner portions of the anterior cornua of the spinal cord." These median nuclei absolutely cease some distance above the point of coalescence between the external and inner portions of the anterior cornua. In fact, there is very little synectic tissue in the canalicular walls at the lower part of the medulla (Plate VI., figs. 3, 4, *c*).

EXPLANATION OF PLATE XI.

Fig. 1. Antero-posterior longitudinal section of the medulla oblongata from the cord to the calamus, and just external to the median fissures ($\times 2$). Right side. *Cal*, grey matter near the calamus; *G*, nucleus gracilis; *g*, prolongation of Goll's column; *Ol*, olivary body; *d*, median grey streak of dendroidal fasciculus. (The late owner of this medulla oblongata was a notorious bully in a low district of this town. His skull was fractured in a drunken brawl. It is the largest specimen in its present possessor's collection.)

Fig. 2. Similar section parallel and external to the preceding. *Cal*, grey matter about canal orifice; *G*, nucleus gracilis; *C*, nucleus cuneatus; *p*, posterior grey column; *ant*, anterior column; *d*, dendroidal fasciculus; *Ol*, olivary nucleus; *f*, fenestrated synectic column.

Fig. 3. Similar section to 1 and 2 only more external. The letters refer to similar parts in the preceding figures.

Fig. 4. Posterior column at the upper part of cord. *p*, Posterior cornu; *l*, synectic interlacement of its central tissue; *ant*, anterior multipolar cornu. Youth.

Fig. 5. Antero-posterior section of medulla just internal to cuneate nucleus. Right side—infant, 6 weeks old. *C*, horizontal grey strands just internal to the cuneate nucleus. The other letters refer to similar parts in the three first figures.

Fig. 6. Antero-posterior longitudinal section of the medulla of an infant through the median line. This section was only hardened by ammonia bichromate and spirit. *CC'*, grey column investing the canal; *d*, grey streak running along anterior border of the medulla; *fa*, transverse fibres.

Fig. 7. Longitudinal antero-posterior section of medulla at the base and about the centre of the olivary body. *a*, External envelope of pia mater; *b*, longitudinal external fibres; *c' c''*, column of grey substance containing multipolar and pyriform cells. Those which pass upwards beside the olivary body belong mostly to the latter class. The synectic stroma *c'* divides into two parts near the vessel *f*, the outer portion *c'''* passes upwards and into the olivary nucleus; *d*, portion of corpus dentatum. Human adult.

THE MUSCULUS STERNALIS. By D. J. CUNNINGHAM,
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Dublin.*

(Read before the Sub-section of Anatomy and Physiology, Academy of Medicine
in Ireland, Dec. 1883.)

THE occasional presence of the musculus sternalis in the human subject has always been an object of great interest to anatomists. This arises chiefly from the difficulty which has been experienced in determining its homologies. The most opposite views have been advanced, and yet the question remains as much unsettled as ever.

The four hypotheses most commonly adopted are :—

- (1) That it is an extension upwards of the rectus abdominis ;
- (2) That it is an extension downwards of the sterno-mastoid ;
- (3) That it is a remnant of the panniculus carnosus, and to be associated in man with the platysma myoides ;
- (4) That it is a muscle peculiar to man, and without a representative in the muscular system of the lower animals.

These views have all been fully discussed by Professor Turner in his very able and elaborate paper upon this subject. Having studied the muscle in no less than twenty-one specimens, his views are especially deserving of attention.¹ He considers that the balance of evidence favours the opinion that it should be classed with the platysma.

Last winter session a new light was thrown upon the nature of the musculus sternalis. Mr P. S. Abraham, curator of the Museum of the Royal College of Surgeons in Dublin, exhibited, at the sub-section of anatomy and physiology of the Academy of Medicine in Ireland, a series of anencephalous foetuses in which the muscle was present. In these the muscle had attained a development rarely seen in the adult subject. The interest of his communication ² was centred not only in the fact that in six out of eleven anencephali which he had examined he found the

¹ *Jour. Anat. and Phys.*, May 1867, p. 246.

² *Trans. Acad. Medicine in Ireland*, vol. i., 1883.

musculus sternalis upon one or both sides, but also in his advancing the view that the muscle in question is an aberrant portion of the great pectoral muscle.

This theory did not receive much support at the time. It was indeed difficult to conceive how a muscle with its fibres running in so different a direction, and axial in its attachments, could be associated with the pectoralis major. As it so happens, however, there is now strong reason to believe that Mr Abraham has arrived at the correct interpretation of the nature of the musculus sternalis.

Two months ago Dr Little, the university anatomist, directed my attention to a well-marked example of the musculus sternalis which was present in a female subject which was being dissected in the Practical Anatomy Rooms of Trinity College. Luckily the parts were quite undisturbed, so I determined, if possible, to make out its nerve of supply.

I knew that, if it were an extension upwards of the rectus abdominis, it would be traversed and supplied by the terminal twigs of the intercostal nerves on their way to the surface; that if it were an extension downwards of the sterno-mastoid, we might expect a twig from the spinal accessory, or at least from the cervical plexus; that if it belonged to the order of the panniculus carnosus, it would probably receive a special branch from the brachial plexus; and lastly, that if it were of the pectoral group it would most likely be brought under the sway of one or other of the anterior thoracic nerves.

An exceedingly minute nervous filament was detected advancing towards it upon the surface of the pectoralis major. On tracing this inwards, it was found to reach the deep surface of the musculus sternalis, and break up into terminal twigs, all of which sank into the substance of the muscle. On following the nerve-filament outwards, it was observed to pass through the pectoralis major and costo-coracoid membrane, and finally join the trunk of the internal anterior thoracic nerve.

It is right that I should state, however, that the anterior thoracic nerves were not quite regular in their origin or position. Both arose above the level of the clavicle by a common trunk, which took origin from the brachial nerves by two roots; both were placed to the outer side of the axillary artery. The identity

of the internal anterior thoracic nerve was nevertheless thoroughly established by its course and distribution. It passed downwards to the upper border of the pectoralis minor. Here it divided into two parts: of these one sank into the deep surface of the small pectoral, whilst the other pierced the costo-coracoid membrane, and the pectoralis major to reach the musculus sternalis. On its way through the great pectoral muscle it gave numerous twigs to its substance. This latter branch, therefore, represented the twig from the internal anterior thoracic nerve, which, under ordinary circumstances, emerges from the anterior surface of the pectoralis minor to aid in the supply of the pectoralis major.

The musculus sternalis, therefore, derives its nerve-fibres by a most circuitous route (its nerve in this instance measured fully $8\frac{1}{2}$ inches in length), and we can only explain this by supposing that it belongs to the pectoral group of muscles; more especially is it brought into close alliance with the great pectoral muscle.

It is unnecessary here to discuss the value of nerve supply in determining muscle homology. Everyone will admit that it is without doubt the most reliable guide that we possess, and in this particular case it points with more than usual force.

**MOVEMENTS OF THE SHOULDER GIRDLE INVOLVED
IN THOSE OF THE ARM ON THE TRUNK. By
CHARLES W. CATHCART, M.B., F.R.C.S., *Lecturer on Anatomy,
Surgeons' Hall, Edinburgh.***

(Read at the Meeting of the British Medical Association held at Worcester,
August 1882.)

IN bringing forward the subject of the present investigation, my object has been a twofold one—first, to draw attention to, and, if possible, confirm the principle of appeal to the living subject in the investigation of questions in animal mechanics; secondly, to give an example of some results obtained in this way. These results will be found to differ considerably from those usually accepted as correct in the movements referred to; and, as the value of the results in any case will depend on the accuracy of the method of investigation employed, and more especially since some authorities have tried to throw discredit on this method in particular, I may perhaps be allowed to begin by saying something in its favour.

In the present stage of scientific inquiry, it may be safely said that *à priori* deductions, however useful in their way, will not be accepted, in the face of actual observations of fact; and that more particularly in questions of physiology, the nearer our field of observation can be made that of the healthy living individual the more reliable are our conclusions likely to be. This has been brought out in the recent discussions as to vivisection, where its opponents seem to differ from its supporters chiefly as to the question of vivisected animals being taken as fair specimens of healthy living phenomena, not so much as to the value of such a field of observation, were it in their opinion thus attainable. We would all, I think, be ready to acknowledge the value of observations on pathological cases, experimental investigations in the laboratory, or deductions from structure taken from a purely mathematical or physical standpoint. These, however, though always most useful, and often, from the nature of the case, indispensable, can only afford us the means of modifying or corroborating, not of displacing or overthrowing, the views we have obtained from examining

healthy living individuals. In many departments of physiology such a field of observation is almost entirely out of our reach, but in most questions of animal, and especially human, mechanics, it is perfectly accessible, and ought to be freely made use of, much more so than has as yet been done. The results obtained by M. Marey's graphic methods on the physiology of the circulation, and on the locomotion of birds and animals, and the revelations of instantaneous photography, as were first shown by Muybridge in the paces of the horse and other animals, might well have shaken our faith in the primary importance of the older deductive methods, yet it is remarkable to observe the tenacity with which some authorities still hold to them. But to pass more particularly to our subject, it is now well recognised that even the simplest movements in the body involve a most complicated co-ordination of muscles and parts of muscles; and therefore, in investigating any question in animal mechanics, unless we could tell not only the exact part of each muscle contracting, but also the exact strength and direction of its pull, as well as the relative shape of the articular surfaces involved, we would not have the necessary premises for any purely mathematical deduction as to what movement ought to take place. When, in addition to this, we remember that the direction, amount, and energy of muscular contraction, as well as the relative position of joint surfaces, changes continuously throughout any movement, we can see the more distinctly how hopeless it will be to substitute *à priori* deductions for the observations of actual fact. Accordingly, therefore, I shall make my first and last appeal, in the present investigation, to the living arm, moving naturally and freely. This will be considered the simplest as well as the most reliable criterion, other means of inquiry being used when necessary, but only as secondary aids to this one.

It may not perhaps be amiss to mention, in passing, that it was in the endeavour to follow out Mr Kean of Philadelphia's plan,¹ and illustrate to my class on the living model as much as possible of the described action of muscles and movement of

¹ "On the Systematic Use of the Living Model as a Means of Illustration in Teaching Anatomy," *Transactions of the International Medical Congress*, held in London, August 1881.

bones, that I was led to see how different the recognised views sometimes were from what were thus shown to be the reality.

The mechanism of the movements which I wish to describe is not fully treated of in any of our English text-books, although in the description of the various joints and of the individual muscles, we may find the materials with which to piece together a connected view of the whole. One quotation from Quain's *Anatomy*,¹ 9th edition, may be taken to illustrate the ordinary view as to the movements of the scapula and humerus in this motion, viz. :—

“The deltoid muscle raises the arm from the side as far as the structure of the shoulder-joint permits, viz., till it is at right angles with the trunk. Further elevation of the upper limb is effected chiefly by the serratus magnus and trapezius.”

If we collect the separate descriptions on this subject, and make them run together, we would find the ordinary view to be something as follows :—

“In raising the arm away from the body, from the hanging position close to the side, up to the full extent above the head, the movement may be divided into two stages—(1) from the vertical below to the horizontal, (2) from the horizontal to the vertical above. In the first of these the head of the humerus moves over the fixed glenoid cavity of the scapula until the great tuberosity touches the acromion process, at which time the arm is horizontal to the trunk. The muscles involved in this are the supra-spinatus to initiate the abduction, and the deltoid to continue it to its full extent; while the supra- and infra-spinatus and subscapularis muscles have the power of steadying the arm, and giving precision to the movement. In the second stage the humerus no longer moves on the scapula, but both move together as the lower angle of the scapula is moved forwards and upwards by a rotation at the acromio-clavicular joint; while at the same time the clavicle is raised by an upward movement at the sterno-clavicular articulation. To effect the rotation of the scapula, the lower fibres of the trapezius and lower portion of the serratus magnus come into play; the clavicular fibres of the trapezius raise the clavicle, and the continued contraction of the deltoid and scapulo-humeral muscles maintain the scapula and humerus in their former relative positions.”

So far as the above description of muscular action is concerned, Duchenne has long ago pointed out.

1. That the supra-spinatus is not required to initiate abduction as the deltoid alone can do this.²

¹ Quain's *Elements of Anatomy*, 9th ed., 1882, vol. i. p. 207.

² *Physiologie des Mouvements*, Baillièrè & Sons, Paris 1867, p. 54.

2. That the supra-spinatus alone can elevate the arm to the horizontal position when the deltoid is paralysed.¹
3. That the simultaneous contraction of the trapezius and serratus magnus is required to steady the scapula as soon as the arm leaves the side.² This he has clearly shown to be necessary to prevent the scapula from being tilted away from the chest wall by the weight of the arm, which, from the fixity of the shoulder-joint, now acts on the scapula through the humerus, as through a single lever having its fulcrum at the acromio-clavicular joint.

In addition, however, to these observations of M. Duchenne, which seem to have been overlooked by many, I should like to point out several important differences in the behaviour of the bones, and of course also in the contraction and co-ordination of the muscles. As to the bones, it may be observed—

1. That the scapula rotates throughout the whole movement in question, with the exception of a short space at the beginning and at the end.
2. That the humerus moves on the scapula, not only from the hanging position to the horizontal, but also in passing upwards as it approaches the vertical above.
3. That the clavicle moves not only in the second half of the movement, as is rightly described by some, but in the first as well, though to a less extent.

In this way we see that the scapula and clavicle are concerned in the first stage of the movement as well as in the second, and that the humerus is partly involved in the second as well as chiefly in the first.

As regards the muscular contraction, it can easily be recognised, by sight and touch, that the upper part of the trapezius—especially the acromial fibres—comes into play as soon as the arm leaves the side, and seems to act in raising the clavicle and in steadying the scapula. The other portions of the trapezius may also be seen to contract although not to the same extent. The action of them all, except the lowest set of fibres, will probably be to steady the scapula by acting against the serratus magnus, and also to antagonise the scapular fibres of the deltoid, which

¹ *Op. cit.*, p. 78

² *Op. cit.*, p. 57.

would otherwise tend to rotate the scapula towards the humerus. Those fibres which pass from below very obliquely upwards to be inserted into the spine near its base will probably contribute at first to the rotation of the bone on the acromio-clavicular joint, by drawing this portion of the bone downwards. As long as the insertion of this part of the muscle remains internal to a line drawn from its origin to the acromio-clavicular joint, these fibres will have this rotatory power; afterwards they can only act in steadying the bone. The continuous hardening of the muscle can be easily felt throughout the movement. The deltoid can be felt to harden simultaneously with the effort to remove the arm from the side, and its further contraction until the horizontal position is reached is of course apparent. In addition it will be seen that when the arm is raised from the horizontal upwards to the vertical, the anterior portion of this muscle contracts still further, as is evidenced by further hardening and alteration in form. The infra-spinatus from its superficial position can be easily watched, and it will be found to contract almost as soon as the arm leaves the side, long before it has reached the horizontal. The serratus magnus again can with difficulty be seen to contract during the first stage, but in the second, especially towards the latter end of it, the contraction is most manifest, as is of course usually described. If we now collect the above statements together, we may describe what may be observed to take place as the arm is abducted from the side, and passes from the vertical below to the vertical above. Having selected a muscular man, with as little as possible of subcutaneous fat, he is stripped to the waist and asked to raise, say, his right arm, in the two stages above described, while his left hangs at his side for comparison.

1st Stage.—It will be seen that while the arm is at rest the vertebral border of the scapula projects from the trunk, and that the venter is not closely applied to the chest wall, but that as soon as an effort is made to raise the arm, the scapula is drawn more firmly against the ribs by the muscles passing to it from the trunk. When the arm in leaving the side reaches an angle of about 30° , the inferior angle of the scapula begins to rotate forwards, while the clavicle (best seen at the acromial end) moves upwards and backwards. From the beginning, the

contraction of the deltoid and trapezius muscles can be seen and felt, as also that of the infra-spinatus, while that of the serratus magnus is with difficulty appreciated.

2nd Stage.—The continued rotation of the scapula is at once evident, and on close examination it will be seen, that while the humerus moves with it at first, towards the end of the movement the scapula ceases to rotate, and the last part is performed by the humerus alone moving over the glenoid cavity; this will be rendered apparent if the direction of the spine of the scapula be compared with that of the humerus in the horizontal position and in the vertical above. The acromial end of the clavicle will be seen to rise and pass backwards, also to have a slight rotation on its long axis. The continued contraction of the trapezius, infra-spinatus, and deltoid muscles is apparent, while the increased contraction of the deltoid at its anterior part, and of the lower portion of the serratus magnus is in each case perfectly clear.

If the arm be now allowed to return to its original position, the bones may be observed to pass again through the various movements described. It is interesting to note, however, that, as the arm is returning to rest, the scapula is pushed from the thoracic wall further than it is at a corresponding position as the arm is being raised, *i.e.*, before it settles against the chest wall, and lies in the somewhat loose position at first indicated. This is probably due to the muscles round the shoulder not having relaxed, while the scapular muscles coming from the trunk *have* done so, consequently the leverage on the scapula from the arm remains, while the antagonising forces are no longer in action.

Infra-spinatus.—It is worthy of note that this muscle is contracted before the arm reaches the horizontal position, consequently it would seem to add a certain power of abduction to its otherwise recognised actions, or at least its contraction does not seem to antagonise abduction, while the arm is still near the side.

As regards the contraction of the anterior portion of the deltoid as the arm approaches the vertical above, Professor Thane has kindly pointed out to me that this might be due to the forward rotation of the humerus along with the scapula, as it moves on the acromio-clavicular joint, and probably this may

partly account for the contraction in question, but that the humerus and scapula have changed their relative positions may be easily made out, if we carefully feel for the spine of the scapula, and compare its direction with that of the humerus when the arm is held horizontally, and when it has reached the last position vertically upwards.

The indistinctness of the contraction of the lower part of the serratus magnus in the early part of the movement deserves a few words of comment; in the first place, the rotation of the scapula at this stage may be partly passive, *i.e.*, by being drawn along with the humerus, on account of the fixity of the muscles about the shoulder-joint; and partly active, due to the scapular portion of the deltoid, which will tend to draw the spine of that bone downwards, unless this action be entirely neutralised by the upper part of the trapezius. The serratus magnus, which probably also helps to rotate by drawing the inferior angle of the scapula forwards, will be called into play more and more as the arm leaves the side, the force required being greater and greater as the arm approaches the horizontal. At first, therefore, not much contracting force being needed, the contraction will not be so manifest as afterwards.

The movements of the clavicle seem to have the effect of bringing the weight of the arm more into line with the axis of the trunk, and therefore to lessen the strain necessary to maintain the body erect.

If, instead of the movements of direct abduction, we substitute that of forward or backward lifting of the arm, similar movements of the scapula may be observed, but the ones I have selected are sufficiently typical of the rest.

I have tried to describe the result of frequent observations on many different individuals, in all of whom the movements have been the same, so that I may conclude that they are physiological in all healthy persons. I trust that I have been able to show how intimately the movements of the arm are associated with those of the shoulder girdle, and to prove that the study of the living subject is not only interesting and important, but also both reliable and indispensable in the study of such questions of human mechanics.

It will be unnecessary to do more than briefly indicate the

value of such knowledge of muscular co-ordination as I have tried to make clear. In diagnosing pains about the shoulder, it comes to be of the greatest importance to know what muscles are normally involved in any of the movements at this joint—affections of the trapezius, for instance, are found to cause pain as soon as the arm leaves the side, the explanation of which is at once clear from what we have already seen. Again, in treating injuries to the shoulder, where it is necessary to give rest to all the parts concerned, an intimate knowledge of the physiology of movement in this region is the only basis for the necessary precautions in each particular case. There especially we see the value of this method of study, for we do not wish so much to know what may be the action of each particular muscle—or what it might be—but what are the usual total movements, what different muscles are involved simultaneously, and what parts of each come into play together.

By the aid of the above results I hope to throw some new light on the mechanism of displacement of fractures of the clavicle. Moreover, by directing attention to the value of the living model for revealing the true relative movements of such large bones as the humerus, scapula, and clavicle, I trust that the way is paved for establishing a more difficult position, *i.e.*, that of the movement of the ulna in pronation and supination, which I hope soon to publish.

ON THE RELATION OF THE ORBITO-SPHENOID TO
THE REGION PTERION IN THE SIDE WALL OF
THE SKULL. By J. B. SUTTON, *Lecturer on Comparative
Anatomy and Senior Demonstrator, Middlesex Hospital.*
(PLATE XII.)

IN the skull of a human foetus at birth, there exists, as is well known, six spaces in relation with the parietal bones, two situated in the median line, named respectively anterior and posterior fontanelle, and two on either side, the anterior and posterior lateral fontanelles; thus each angle of the parietal bone at birth is in relation with a membranous space. The original situations of the lateral spaces are identified in the adult skull by appropriate names, the posterior lateral becomes the *asterion*, marking the meeting-point of three sutures—lambdoid, parieto-mastoid, and occipito-mastoid. If an interparietal bone is present, a fourth suture is added to the list, and very frequently, especially if young skulls be examined, a Wormian bone occupies the space.

The site of the anterior lateral fontanelle is recognised as the *pterion* in the mature skull. It is the meeting-point of several sutures, which vary in their relation to one another.

Professor Flower has drawn attention to the fact, that, in many instances, where the frontal and squamosal bones articulate so as to give rise to a vertical fronto-temporal suture, the union is brought about by means of a Wormian bone, often found in this space, uniting with the frontal or squamosal, this intercalary ossicle he termed the *epipteric bone*. While endeavouring to inquire into the question as to how far Professor Flower's observations would hold good, I was led to notice certain anatomical relations between this space and the orbito-sphenoid, which I propose to embody in the present paper.

Anatomists are well aware that in the skull of the horse the size of the orbito- and alisphenoids is reversed, the term lesser wings is no longer applicable to the orbito-sphenoids, for they are larger than the alisphenoids, and take a considerable share in the formation of the side wall of the cranium. If a colt's

skull be examined shortly before birth, a narrow fissure may be observed in the frontal bone near its junction with the parietal, at the point corresponding with the pterion in the skull of man. This fissure lodges the anterior rounded border of a plate of hyaline cartilage. If the skull be bisected, or, better, disarticulated, a plate of cartilage will be noticed of the size and shape shown in fig. 1, capping the anterior extremity of the orbito-sphenoid. After birth, ossification extends into this cartilage, so that in the adult skull the orbito-sphenoid is in contact with the frontal, parietal, and squamosal.

On two occasions I have seen ossification take place from an independent nucleus at the superior extremity of this piece of cartilage, E in fig. 1, and this is one of the reasons for my stating that the epipteric bones probably arise in cartilage left by the orbito-sphenoids.

If the skull of a human foetus be examined between the fourth and seventh month before it is put into alcohol (for this mode of preparation causes delicate cartilage to shrink greatly), and the dura mater carefully dissected from the posterior boundary of the anterior fossa, this membrane will be found to form at this part a narrow tube running from the anterior clinoid process to the pterion, containing a strip of cartilage. This piece of cartilage at the fourth month is relatively large, and represents the orbito-sphenoid; as ossification proceeds it is encroached upon, but at the sixth month the piece of cartilage occupying the fontanelle is often club-shaped and of considerable size. After the seventh month the cartilage gets very thin and delicate, so that at birth it merely forms a thin layer along the posterior border of the orbito-sphenoid, as shown in fig. 2.

Therefore, in the chondro-cranium of the human foetus and in the earlier stages of the osseous skull, the outer extremities of the *orbito-sphenoids form part of the side walls of the cranium*.

By the atrophy of this piece of cartilage, an unclaimed area exists in the cranium. A piece of debateable territory and an examination of the adult skull would show that four neighbouring bones struggle for the mastery.

In the mature skull the result may vary in four ways:—

1. The anterior inferior angle of the parietal bone may be prolonged downwards anteriorly to the squamosal, in order to

articulate with the sphenoid, thus shutting off the squamosal from the frontal.

2. The squamosal may occupy the space and form a fronto-squamosal suture. In this case the coronal suture becomes continuous with the fronto-squamous and sphenosquamosal sutures as shown in fig. 3.

3. Occasionally the alisphenoid extends upwards to join the parietal, and sends a narrow strip of bone backwards so as to shut off the anterior portion of the squamosal from union with the anterior inferior angle of the parietal. This is not by any means uncommon.

These varying conditions depend on the behaviour of the epipteric bone as follows:—

4. The epipteric bone (fig. 4).

In all the human skulls I have been able to examine under the age of fifteen years, this bone has been present. The youngest skull in which it has been observed was one year old. It seems to be developed in the cartilage left by the lesser wing of the sphenoid in the anterior lateral fontanelle, and may vary in size from a pea to a bone half an inch square, or even larger in many cases. It would seem to develop, as far as I can ascertain, about the first year. It may do one of five things.

1. It joins occasionally the squamosal, as shown by Professor Flower.

2. That it joins the alisphenoid in some instances is equally certain, for in some skulls traces of a suture are visible on the outer aspect of the skull, but obliterated on the inner surface.

3. It may ankylose with the frontal, and in this way exclude the parietal from articulation with the sphenoid.

4. Most commonly it fuses with the parietal, constituting its anterior inferior angle.

5. That the ossicle occasionally remains as a separate element of the skull is beyond doubt, for it may be detected in skulls when most of the sutures are completely closed, and the skull edentulous through age. In this it resembles the frontal, for when the two halves of that bone fail to unite at the proper time, they frequently remain separate throughout life. The early ankylosis of the epipteric ossicle with the neighbouring bones, is in accordance with the rule, that those sutures which

are the last to form are usually the first to suffer obliteration.

The following points seem clear, viz., that the pterion is probably always occupied by the epipteric bone, which must, therefore, be reckoned as an integral part of the skull. When this ossicle is small, the neighbouring bones conspire to fill up the deficiency. If the bone is large, it may ankylose either with the alisphenoid, frontal, squamosal, or follow the more usual course and unite with the parietal, but exceptionally it may remain separate and distinct throughout the whole of life.

Sufficient facts have now been adduced to prove that the epipteric bone differs in its nature from those singular intercalary ossicles which infest the cranial sutures, and that it should take a place with the intrinsic bones of the cranium, of which I have endeavoured to show it to be, so far as man is concerned, a constant element.

I have met with numerous skulls of monkeys, dogs and other carnivora, and sheep, in which this little bone was clearly defined, situated immediately anterior to the alisphenoid, so that the term *epipteric* is a very suitable one. In monkeys the presence of this ossicle is most commonly observed in young skulls, from the interior of the cranium. Often no trace of it can be detected when viewed from the outside, whilst its suture is plainly visible on the inside. There remains yet one point of interest in connection with this ossification. Its immediate relations to the parietal, frontal, squamosal, and alisphenoid, recall strongly those of the crocodile's post-frontal, which has offered so much resistance to "homology" since the days of Cuvier.

EXPLANATION OF PLATE XII.¹

Fig. 1. The basi-cranial axis of a colt's skull at birth. O.S. Orbito-sphenoid (so-called lesser wing) with its cartilage. B.S. Basi-sphenoid. B.O. Basi-occipital. E. This piece of cartilage is often ossified from an independent nucleus.

Fig. 2. The orbito-sphenoid of man at birth. O.S., orbito-sphenoid with its cartilage. C, which occupies the pterion. B.S. Basi-sphenoid with the lingulæ. L.L. for the ali-sphenoids.

Fig. 3. The squamosal S. joins with the frontal F. at the pterion P. From a native of New South Wales.

Fig. 4. The epipteric bone, E.

¹ Plate XII. will appear in the April number of the *Journal*.

Anatomical Notices.

A SECOND SPECIMEN OF A FIRST DORSAL VERTEBRA WITH A FORAMEN AT THE ROOT OF THE TRANS- VERSE PROCESS.

SINCE I described a specimen of this variation in the first dorsal vertebra a year ago in this *Journal* (Jan. 1883), I have obtained a second specimen, which was presented to me a few weeks ago by one of my pupils, Mr W. C. Sprague.

It was found in a skeleton purchased from a dealer. It occurred on the right side only, immediately in front of the superior articular process and in the outer side of the pedicle of the neural arch, and the foramen was of sufficient size to admit an ordinary sized knitting needle. It was vertical in direction, and its anterior boundary was formed by a slender bar of bone which arose from the outer surface of the root of the pedicle, and passed transversely outwards to join the transverse process. The left side of this vertebra was normal. The seven cervical vertebræ were all present, and each possessed a characteristic foramen at the root of the transverse process. The ribs were normal, and the first rib had the usual articulations both with the body and transverse process of the first dorsal vertebra.

In this, as in the previous instance, this foramen is obviously not homologous with the foramen at the root of the transverse process of a cervical vertebra, and has probably been developed in connection with the passage of a vein.

W. TURNER.

THE BRAIN OF A CAT LACKING THE CORPUS CALLOSUM.

SPECIMENS of human brains have from time to time been described in which the corpus callosum was absent or defective. Professor Burt G. Wilder has now put on record (*American Journal of Neurology and Psychiatry*, August 1883) an account of a brain in a cat, about three-fourths grown, in which the corpus callosum had not been developed. The anterior and middle commissures were both absolutely and relatively larger than in an adult normal brain, which suggests the idea that the functions of the callosum may have been performed by these two commissures. All that would commonly be called fornix seemed to be the fimbriæ on the two sides—the lyra was wanting.

THE OS INTERMEDIUM TARSI IN MAMMALIA.

PROFESSOR PAUL ALBRECHT has made a short communication *Zoologischen Anzeiger*, Leipzig 1883, p. 419) on the occurrence of this bone, and he refers to a previous paper by Dr Bardeleben on the same subject. The bone has been named os trigonum, and he considers it to be homologous with the os intermedium or semilunar bone of the carpus. He figures a specimen from the human tarsus in the Königsberg Anatomical Museum, and from his figure it would seem as if this bone was the same as that ossicle which Professors Gruber and Turner had described as a "secondary astragalus," and which Dr F. J. Shepherd thought was due to a fracture of the posterior border of the astragalus (*Journ. of Anat. and Phys.*, Oct. 1882).

ON THE FOUR INTERMAXILLARY BONES.

PROFESSOR PAUL ALBRECHT has published a second memoir on this subject (*Bull. de la Soc. d'Anthropologie de Bruxelles*, 1883), in which he advances additional illustrations in support of his view that there are four intermaxillary bones in the hard palate, viz., an internal and an external on each side, which are separated from each other by a suture that emerges in front between the central and lateral incisors. He states that in cleft palate extending through the alveolar border of the jaw, the fissure lies between the internal and external intermaxillary bones, and not between the external intermaxillary and the superior maxilla. The upper outer incisor in man is homologous with the third incisor in many quadrupeds, and it is situated in the external intermaxillary bone, and when three incisors occur on one side, two are placed in the internal intermaxillary bone. In some cases of cleft palate the more external of these two incisors, which in normal development is not formed, may be produced, and it is then lodged in the internal intermaxillary bone.

Fig
x 2



Fig. 5
x 2



Fig. 6
x 2



Fig. 7
x 2





δ

γ

δ

γ

γ

δ

γ

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γ



A M N

F. Smith, Lith. Edin.

Fig 1

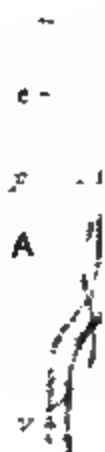


Fig 2.



Fig. 3



Fig 4



Fig 5



Fig 8



Fig 9



Fig 10



Fig 11



Fig 13



Fig 12.



Fig 14



Fig 6



Fig 7



Fig 15.



Fig 16

ce

Fig 23.

c

Fig 18



Fig 24

v p

Fig 17

m

h

Fig 19



Fig 20

m

c

Fig 25.

Fig 27



Fig. 21.

ce

e

h

c

Fig 28.



Fig 26

m

c

Fig 29



m

c

p

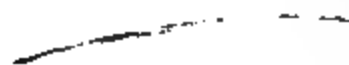
Fig 22

n

p



ce





Journal of Anatomy and Physiology.

ON THE NATURE OF CERTAIN LIGAMENTS. By J. B. SUTTON, *Lecturer on Comparative Anatomy, and Senior Demonstrator of Anatomy, Middlesex Hospital Medical College.* (PLATE XIII.)

MÜLLER'S *Archiv.* for 1834 contains a short paper by Professor Mayer of Bonn, entitled "Ueber ein neuentdecktes Band, Jochband der Rippen (Ligam. costarum conjugale)." Under this title Professor Mayer describes a ligament which he discovered in the calf, as a round band serving to fasten the head of the rib in the articular depression intended for its reception. This *ligamentum costarum conjugale*, which will be carefully described later, he found in the dog, fox, wolf, bear, badger, horse, pig, rabbit, ape, and cat; but in man it is reduced to the small interosseous ligament attached to the head of a rib. This observation remained neglected until 1858, when Professor Humphry, in describing the transverse ligament of the atlas in his work on the *Human Skeleton*, refers to Mayer's article in a footnote on page 314.

In the year 1859, Professor John Cleland, at that time demonstrator of anatomy in the University of Edinburgh, published a paper, in the *Edinburgh New Philosophical Journal*, on "The Structure, Actions, and Morphological Relations of the Ligamentum Conjugale Costarum," the main points of the paper having been previously read at a meeting of the Royal Society of Edinburgh, in March 1858, by Professor Goodsir. In this paper Cleland writes:—"The ligament alluded to is one which has not hitherto been sufficiently described, or had its importance duly appreciated." Veterinary authors merely mention it as fibres from the interarticular ligaments of the head of

the rib of one side, continued across the middle line above the intervertebral disc to that on the other.

It appears that Cleland, unaware of Mayer's observations, met with the conjugal ligament accidentally in the seal, the animal of all in which it is best developed. This is singular, for it was while engaged in examining the vertebral column of a seal at the Zoological Gardens I first noticed the ligament, also unaware of Mayer's paper and Cleland's observation. I have to thank Mr Henry Morris, to whom I showed the ligament, for drawing my attention to Cleland's paper; and, as his description of the ligament in the seal agrees in every respect with my dissections conducted on two of these animals, it will be satisfactory to reproduce it:—

None of the ribs of the seal have the articular surface of the head divided in two, but each of those which arise opposite intervertebral discs has a depression on the inferior margin of its articular surface similar to that on the head of the femur, and from this springs a strong and rather flat ligament which, sheathed in synovial membrane, passes above the intervertebral disc, and is attached in the same way to the rib of the opposite side. It lies close upon the disc which is grooved for it, and is covered by the superior common ligament. As it nears its attachment at each side, it is flattened out, so as to lie like a fibro-cartilage between the rib and the intervertebral articular surface; and the head of the rib rolls on this structure. The synovial investment of the ligament and upper edge of the intervertebral disc is continuous with the joint on either side, so that there is one common synovial capsule in connection with the articulation of the heads of each pair of ribs to the vertebræ. The first pair of ribs and the last four pairs being articulated, each with only one vertebra, have no such ligament; and in connection with the second and eleventh pairs, the ligament is smaller than in the other cases (fig. 1).

The ligament is present in the lion, otter, fox, and dog, but the communication of the synovial cavities across the intervertebral disc does not exist. Its presence may be demonstrated in the weasel, squirrel, rabbit, calf, and sheep, with slight modifications.

A lengthy account is then given of its probable functions, the

sum and substance of the argument being that its use is not so much to effect a harmony in the motions of the ribs as to limit their action without disturbing their harmony.

As soon as I observed the ligament in the seal, ignorant of the writings of the above-mentioned anatomists, I dissected out the structure in a great number of mammals, and, finding the ligament exceedingly general, I thought that it might possibly exist in man; so it was sought for, not in an adult column, but in the spinal column at birth.

In the human foetus, from the seventh month onward to birth, the *ligamentum conjugale costarum* may be found as a well-marked band passing on the posterior aspect of the intervertebral disc from the head of the rib of one side to the corresponding rib head on the other. Its existence may be best demonstrated in the middle of the thoracic portion of the vertebral column. If one of the ribs on the left side, say the sixth, be carefully detached from its attachments to the transverse processes and the bodies of the vertebræ, leaving the interosseous ligament intact, this may easily be traced across the intervertebral disc, continuous with the corresponding structure attached to the rib on the right side, as shown in fig. 2. Very quickly after birth (within six months) it fuses with the disc in front, and contracts an intimate union with the posterior common ligament of the vertebral bodies, and ceases to exist as a definite structure except at the extremities, which are attached to the ribs, and serve to divide the synovial cavity into two distinct chambers. At no date have I found in the human foetus a synovial channel running across the intervertebral discs and connecting the synovial capsules of the rib heads as it exists in the common seal.

It seems not a little strange that this structure should have been so overlooked. Even Dr Murie, in his very exhaustive account of the anatomy of the sea lion, does not make mention of it; and a later writer, Mr St George Mivart, in his very elaborate work on the *Anatomy of the Common Cat*, fails to mention the ligament.

More than ordinary interest attaches itself to this band than to ligaments in general, for there can be little doubt that, as suggested by Cleland, "it must be considered as containing an important vertebral element, notwithstanding its immediate

disappearance in the segments where ribs are connected with only one vertebra." In support of this opinion of Cleland, it is well for me to mention that Balfour, in his *Comparative Embryology*, vol. ii. p. 455, writes :—

"In the tail of scyllium, raja, and possibly other forms, there are double as many vertebral bodies as there are myotomes and spinal nerves. This is not due to a secondary segmentation of the vertebræ, but, as I have satisfied myself by a study of their development, takes place when the vertebral bodies first become differentiated."

Apart from such speculation as this stands the notion that the transverse ligament of the atlas is a structure of the same description, as Mayer and Cleland both recognised; and the singular condition of the ligament in the seal, explains in a beautiful way the existence of a synovial cavity in so curious a situation as the back of the odontoid process. May it not also serve as an additional argument for those anatomists who maintain, that in the anterior portion of the transverse process of a cervical vertebra we may recognise a rib rudiment, or rather, remnant. One may even advance further and say, that the check ligaments passing from the tip of the odontoid process to the little tubercles on the inner side of the occipital condyles are modifications of the same ligament, and thus add additional proof to the almost accepted doctrine that the occipital segment of the skull is a modified vertebra.

To say the least, it will increase the student's interest in this complicated joint to reflect that the transverse and check ligaments are representatives, in the cervical region, of the *ligamentum conjugale costarum* found in the thoracic region of the spinal column in many animals, and in the human foetus at birth, as does the fact that the suspensory ligament marks the track of the notochord into the base of the skull, as Rathke pointed out many years ago, when he insisted that the odontoid process of the axis is in reality the body of the atlas (*Ueber die Entwicklung der Schildkröten*).

I must now pass on to consider certain ligaments of the appendicular skeleton, commencing with some additional remarks on the *ligamentum teres*.

On certain Ligaments in the Limbs.

The *Journal of Anatomy and Physiology*, vol. xvii. January 1883, contains a short article on the ligamentum teres, in which I have endeavoured to point out that many ligaments are the *tendons of muscles* which were originally in relation with the joint; but the parent muscle has either formed new attachments or become obsolete, whilst the tendon remains as a passive element in the articulation. In addition to the ligamentum teres the following structures must be placed in that category viz.:—the internal and external lateral ligaments of the knee-joints, the long and short plantar ligaments, and the interosseous membrane of the fore-arm and leg.

Since writing the article on the ligamentum teres, I have had an opportunity of dissecting a very young ostrich, in which the continuity of muscle and tendon does not admit of the slightest doubt (fig. 3). But the arrangement of the muscles differed somewhat from the condition found in the older bird. The ligament itself was not continuous with the ambiens, but with a muscular slip which ran parallel with the muscle, and ended in the adductor mass. (fig. 3). This may possibly represent the inner slip of the pectineus of mammals, and is to be regarded as an anomaly inasmuch as it was separate from the ambiens muscle.

The Internal Lateral Ligament of the Knee-joint.

That the internal lateral ligament of man's knee-joint was in some way connected with the muscles round about the joint, is a conviction long ago forced upon my mind, in consequence of numerous dissections conducted upon the joints of the limbs in many of the quadrumana. This conviction received further support when, on dissecting the muscles of a young orang, I found the tendon of the adductor magnus muscle continuous with the internal lateral ligament, as shown in fig. 4.

On looking into the arrangement of the adductor magnus and the internal lateral ligament in a human foetus at the fourth month of utero-gestation, an age at which the proportions of the various parts of the limbs to one another are more or less anthropomorphous, it was with much satisfaction that I noted,

—the adductor magnus muscle is only connected with the back of the femur by loose connective tissue (the linea aspera does not exist in the foetus), it then gains a slight attachment to the internal condyle of the femur, and continues onward to the head of the tibia as the internal lateral ligament, thus absolutely establishing the fact that this ligament is the tendon of the adductor magnus muscle separated in consequence of skeletal changes to be described later on.

The External Lateral Ligament of the Knee-joint.

Every student engaged in dissecting a knee-joint must have had his attention arrested by the beautiful, rounded, cord-like condition of the external lateral ligament. The notion of it being, or rather that at some time it had been, the tendon of a muscle seems irresistible, and this suspicion is strengthened on finding occasionally in young subjects a synovial sheath investing it.

After dissecting this joint in a large number of animals, the muscles to which it could possibly have belonged were limited to two,—the peroneus longus and the extensor longus digitorum pedis muscles. I shall now endeavour to show that this external lateral ligament is in reality the tendon of the peroneus longus muscle, which has become gradually separated from the belly of the muscle, and formed a new attachment to the head of the fibula. The extensor longus digitorum muscle may be safely excluded for this reason: in many animals this muscle takes origin from the external condyle of the femur, *e.g.*, hyrax, pig, horse, hare, and the orang among apes, and in the ostrich among the birds, and at the same time a well-developed external lateral ligament may be found quite apart and in no way connected with this muscle. On the other hand, the peroneus longus muscle often may be found connected with the ligament, as in the opossum, in the domestic ox, and, what is more pertinent to this question, in the gibbon (*Hylobates leuciscus*), the tendon of the peroneus longus arises from the external condyle of the femur, and replaces the ligament, the tendon itself having no attachment to the head of the fibula (fig. 5). This arrangement leaves the fibula free to submit to the action of the well-developed

rotator-fibulæ muscle which I have observed in this example of long-armed ape, and exhibited in fig. 6.

In all such questions as these, direct *continuity* of tissue is the thing to seek after, then no one can conscientiously doubt the opinion set forth. If a human foetus be examined from the twelfth week up to the fourth month, dissection will reveal the peroneus longus muscle arising from the external condyle of the femur, the tendon at that early date having only a slight attachment to the head of the fibula, easily overcome by gently pulling on the tendon, muscle and ligament will be found directly continuous.

The Long and Short Plantar Ligaments.

If the hind leg of a horse be examined, a strong ligament, passing from the posterior surface of the os calcis to the cuboid and head of the rudimentary external metatarsal bone, may be readily dissected. This fibrous band is known as the calcaneo-metatarsal ligament, near the origin of this ligament from the calcaneum, the tendo Achillis, or combined insertion of the gastrocnemius and soleus muscles is inserted. In the foetal horse, and also in the immature deer, I find that the tendo Achillis and the calcaneo-metatarsal ligament form one continuous structure. This fact supplied a hint for future guidance. Of course it would be most illogical to say, that because the tendon and ligament were one structure in a limb so peculiarly modified as in the horse, the same source of the ligament could be maintained for the origin of the long and short plantar ligaments of man's foot. However, such is indeed the case beyond all doubt, If a human foetus, even as late as the sixth month of intra-uterine life, be examined, by making a section vertically through the tendo Achillis, os calcis, and cuboid, it will be seen that ligament and tendon form one continuous band, and that the attachment of the tendon to the under surface of the os calcis is only of the loosest kind. After the seventh month of intra-uterine life, the tendon becomes divided by extra growth occurring at the posterior extremity of the os calcis, the anterior portion becoming long and short plantar ligaments, the other gaining a permanent attachment to the lower border of the os calcis.

The Interosseous Membrane of the Fore-arm and Leg.

In the iguana, gecko, chameleon, menopoma, and sphenodon (*Hatteria*), a muscle exists, the fibres of which arise from the fibula and are inserted into the tibia, replacing the interosseous membrane. This muscle has been named the peroneo-tibial. It also exists in the wombat.

If the interosseous membranes of the fore-arm and leg in man were not derived from a peroneo-tibial muscle originally, they are at least the morphological representatives of that structure, and as the muscle occurs within the mammalian circle it is not unreasonable to look upon these interosseous membranes as degenerated muscles.

Remarks.

Can any explanation be offered to satisfy the question, Why do these tendons lose their muscular fibres or become separated from the parent muscle? The answer is probably to be found in the very remarkable series of changes the different parts of the body undergo at various periods of intra-uterine life. Professor Huxley in his *Anatomy of Vertebrated Animals*, p. 417, sums them up very concisely thus:—

“In a foetus an inch and a half long, from the vertex to heel, the head takes up from one-third to one-fourth the entire length. The arms and the legs are of about the same length, and are shorter than the spine. The fore-arm is about as long as the upper arm, and the leg as the thigh. The manus and pes are very similar in size and form. In a foetus rather more than five inches high, the head occupies a fourth of the entire height; the arms are longer than the spine by one-sixth of their whole length, and are a little longer than the legs. The fore-arm is about as long as the upper arm, and the thigh is a little longer than the leg. The manus and pes are about equal in length. In a foetus eight and a half inches high the head measures less than a fourth of the whole height. The arms are longer than the spine by about a fourth of their whole length, and they are longer than the legs. The extremities of the digits reach down to the knee when the body is erect.

At full term the height of the head of the human foetus is rather less than a fourth that of the whole body, and the legs

are longer than the arms. The arm is longer than the fore-arm and the thigh than the leg. The hands and the feet are still about equal in length. Thus it would appear, that while the head grows more slowly than the rest of the body throughout the period of gestation, after the embryo has attained more than two inches in length, the arms grow proportionally quicker than the body and legs in the middle of gestation, when the proportion most nearly resemble those of the *Anthropomorpha*. In the latter part of the period of gestation the legs gain on the arms, and the proximal segments of the limbs on the distal ones. After birth these changes are continued. The adult has on the average three and a half times the height of the new-born child, and his arms are elongated in the same proportion. But the head is only twice as large, while the legs of the adult are five times as long as those of the child. At all ages after birth the distance between the extremities of the digits of the outstretched arms is equal to the height in average Europeans.

These facts help one to comprehend why the relations of the muscles to the tendons become disturbed. So long as the segments of the limbs equal one another up to the mid period of gestation, the particular muscles referred to in this paper, and possibly others also, maintain a normal relation to their respective tendons. In the latter half of intra-uterine life, when the proximal segments of the limb grow inordinately, these tendons differentiate into ligaments.

In the *Anthropomorphæ*, as every anatomist knows, the distal segment of the leg equals (or nearly so) the proximal, and the mature condition of the muscles, peroneus longus, extensor longus digitorum pedis, adductor longus, and gastrocnemius, with the soleus, in so far as the origin of the first two and the insertion of the three last are concerned, approximate very closely to the condition I have described as existing in the foetus of man at the fourth month.

Another fact worthy to be borne in mind concerning the peroneus longus is, that during a certain period of intra-uterine life, and often persisting at and long after birth, the foot is in the position known as equino-varus. This position of the foot is not present at first, and it is very difficult to assign an exact date at which this singular position is assumed by the foot; but

this much may be stated unreservedly, that at the fifth month the foot may be always found in this condition:—

The soles of the feet face towards the median line and to one another, so that the dorsum of the foot looks obliquely outwards and somewhat upwards; the heel is drawn slightly upwards, the toes being as a necessity pointed downwards; the inner border of the foot looks upwards and forwards, and the outer border downwards and backwards.

When the foot passes into this condition the peroneus longus must, of all the leg muscles, be much stretched, and it is at this period that in all probability the tendon acquiring its new attachment to the fibula secedes from its original relation to the muscle.

This stretching action is observable not only in muscles. The common carotid and iliac arteries furnish material for similar argument. Early in foetal life there exists practically no neck, and the spaces between the last ribs and crests of the ilia are very narrow, so that there is no need for these arteries. By and by, when growth ensues rapidly, the neck elongates and the pelvis recedes from the ribs. The arterial trunks elongate, and two single branchless stems form in the neck, common carotids, and two similar ones in the abdomen, common iliacs, a process analogous to the transformation of the tendons of the muscles we have been considering into ligaments.

Long ago Professor Humphry (*Observations on Myology*, p. 142, and *Journal of Anatomy*) conceived the muscles of the limbs arising as conical sheaths of muscular fibres investing protruding limb rudiments, and becoming divided and annexed to successive limb segments as such limb rudiments become developed and segmented, finally assuming the form of a median and two lateral groups of muscles both on the extensor and flexor surfaces of each limb.¹ Therefore, I think it reasonable to suppose that in the instance of such muscles as the extensor longus digitorum and tibialis anticus being attached to the femoral condyles in many animals, is, as it were, the final indications of a segmental process found in a rudimentary condition in many amphibians, but more or less perfected in the higher Mammalia.

¹ Mivart, *Elements of Anatomy*.

Examples of the Degradation of Muscles.

Among the more remarkable instances of the degradation of muscle into fibrous tissue to serve as ligaments, must be mentioned the muscles in the fore-arm of certain whales. Professor Struthers gives a detailed description of them in his paper "On some Points on the Anatomy of a Great Fin Whale" (*Balaenoptera musculus*), *Journal of Anatomy*, 1871.

Compared with man, the muscles in the whale's paddle corresponded to the following muscles:—Flexor carpi ulnaris, flexor profundis digitorum, flexor longus policii, and an extensor communis digitorum. Although of vast size when compared with the human limb muscles, yet they are rudimentary structures. Professor Struthers considers it probable that fore-arm and finger muscles will be found to exist in most, if not in all, whalebone whales, and in others among the delphinoid cetacea, he having dissected them in a bottlenose whale (*Hyperoodon*).

But the interest centres itself in the narwhal, of which Professor Struthers possesses a dissection, showing the presence of these muscles morphologically, but histologically they are throughout represented by *fibrous tissue*, and *functionally they are ligaments*.

A very interesting example of the conversion of a muscle into a ligament is met with in the suspensory ligament of the fetlock of the horse and allied animals. As it furnishes independent testimony to the notion expressed in this paper, that ligaments do arise from tendons of muscles, it is necessary to enter a little into detail concerning this interesting structure.

William Percivall, in his excellent work on the *Anatomy of the Horse*, published in 1858, premises his account of the suspensory ligament, by stating that Bourgelat has regarded it as a tendon—"le tendon suspenseur du boulet," Girard as a muscle—"m. tarso-phalangien." He then goes on to describe the ligament after this manner:—

"The suspensory ligament (so called, I imagine, because the sesamoid bones seem to be suspended by it) is perhaps the strongest in the whole body, and is remarkable for its high degree of elastic property. It takes root, superiorly, in a

projection at the upper and back part of the cannon (metacarpal bone), whence it passes, enclosed within a cellular sheath, between the splint bones (rudimentary metacarpals), filling up their interspace. Opposite to about the terminations of these small bones it splits into two divisions, which, diverging in their descent, become implanted into the lateral and posterior parts of the sesamoid bones, and into the fibro-cartilaginous substance uniting them. From the places of implantation two lateral slips are continued from it downward and forward to join the extensor tendon. Between the suspensory ligament, enveloped in adipose membrane, are some large *bursæ mucosæ*. In composition and texture this ligament possesses peculiarities: it has a sanguineous tinge anteriorly, which is not perceptible in other ligaments or in tendons, and its fibres, which are very coarse, are disposed in layers. But its chief peculiarity consists in its exhibiting an intertexture of delicate, pinky, *fleshy* fibres, which appear to be the uniting membrane of the ligamentous fasciculi."

In the *Journal of Anatomy*, vol. xviii., October 1883, Professor Cunningham contributes an interesting paper on "The Development of the Suspensory Ligament of the Fetlock in the Fœtal Horse, Ox, Roe-deer, and Sambre-deer," in which he shows most conclusively that this ligament is formed by the fibrous transformation of the short flexor muscle of the middle digit, and further, that the corresponding structure in the ox, sheep, and camel is developed by the coalescence and fibrous metamorphosis of the short flexor muscles of the middle and annular digits.

Mr Morris, in his *Anatomy of the Joints of Man*, 1879, points out that the tendons of origin of the hamstring muscles may, by a very little dissection, be seen to pass onwards into the great sacro-sciatic ligament, and by pulling on either one of the muscles the whole ligament is tightened. By traction on the biceps the coccyx can be made to move on the sacrum. In fact, the ligament may not be unfairly described as a tendinous expansion of these muscles (page 133). The relation of the biceps at its origin to the ligament is also illustrated on Plate XII. of the same work.

The following table shows the antecedents of those ligaments

which have been described in the preceding pages. No doubt several other ligaments, such as the crucials of the knee-joint, the coraco-acromial of the scapula, &c., have a similar origin, but many, as the fibrous bands of the elbow-joint, are due to thickenings of capsular ligaments, for they are reproduced when that joint is excised by the surgeon.

Ligaments of the Axial Skeleton.

Ligamentum suspensorium dentis.	Marks the course of the notochord from the body of the axis into the basi-occipital.
Check ligaments of axis. Transverse ligament of atlas.	Representatives of the ligamentum conjugale costarum of the seal and many other mammals, and present in the human foetus at birth.
Long internal lateral ligament of the temporo-maxillary articulation.	Remains of the fibrous sheath which at one time enclosed Meckel's cartilage.
The stylo-hyoid ligament.	Remains of the sheath which invested the cartilage connecting the styloid process with the basi-hyoid in intra-uterine life.

Ligaments of the Appendicular Skeleton.

Great sacro-sciatic ligament.	Probably belonged to the hamstring muscles.
Ligamentum teres.	Represents tendon of the pectineus muscle.
External lateral ligament.	Tendon of peroneus longus.
Internal lateral ligament.	Tendon of adductor longus.
Long plantar ligament.	Tendon of gastrocnemius.
Interosseous membrane of leg and fore-arm.	Interosseous muscle of sphendon, &c.

In conclusion, I would remark that ligaments have too long been considered as entities apart from the other structures of the body, and they are neglected by the general student, but I know

from practical experience, that, if some interesting fact can be coupled with these apparently uninteresting bonds, a new and lively interest is awakened, and a healthy stimulus given to a desire for more scientific and less matter of fact knowledge in human anatomy.

EXPLANATION OF PLATE XIII.

Fig. 1. A thoracic vertebra of a seal (*Phoca vitulina*), showing the ligamentum conjugale costarum passing across the back of an intervertebral disc to join the heads of two opposite ribs. The synovial sheath is omitted in order to avoid complicating the figure.

Fig. 2. A sixth thoracic vertebra, with the heads of the corresponding ribs from a foetus (human) at birth. It shows the ligamentum conjugale costarum, as in preceding figure.

Fig. 3. The left femur of a very young ostrich (natural size), showing the continuity of the ligamentum teres with muscle. A. The place where the ligament is attached to the acetabulum.

Fig. 4. The right knee-joint of a young orang, showing the continuity of the adductor magnus muscle, and the internal lateral ligament of the joint.

Fig. 5. The right femur, tibia, and fibula of a human foetus at the fourth month, showing the insertion of the adductor magnus muscle into the head of the tibia.

Fig. 6. Outer view of the knee-joint of a gibbon (*Hylobates leuciscus*), showing the tendon of the peroneus longus muscle playing the part of the external lateral ligament of the joint.

Fig. 7. Posterior view of the same joint to show the rotator fibulae muscle. The popliteus muscle is turned upward and inwards.

Fig. 8. A tibia and fibula from sphenodon, showing the peroneo-tibial muscle. The representative of the interosseous membrane in mammals.

**SOME REMARKS ON NERVOUS EXHAUSTION AND
ON VASO-MOTOR ACTION. By F. LE GROS CLARK
F.R.S.**

NERVOUS exhaustion is an indefinite expression, because it is often used in a lax way; yet it has a very definite meaning, and signifies a condition which it importantly concerns all, whether physicians or surgeons, to be familiar with in the treatment of disease.

Nervous exhaustion is met with in various conditions of the system, and under different circumstances. Its characteristics and the indications of its presence are by no means uniform. It may be the consequence or cause of physical depression, but the two are always more or less allied. Apart from organic disease, such physical depression as muscular debility or assimilative infirmity is rarely prolonged after nervous renovation; but exhaustion or its effects, consequent on overtaxed energy of whatever description, often survives the cause.

The meaning of nervous exhaustion I apprehend to be a more or less general depression of vital energy, depending on a failure in the supply of nerve influence, whatever that may be. The battery is exhausted, the electricity is but feebly generated, and the agencies dependent on this supply falter, become erratic, or fail.

This exhaustion may be transient, or it may be enduring or rapidly fatal. Ordinary muscular fatigue from physical exertion, or weariness from mental tension, is relieved by repose of the great generator of muscular and intellectual force. A brief period of suspended activity of the brain in sleep suffices to restore its generative power for the succeeding day; for even muscular fatigue means nervous exhaustion, and gains but little, if anything, from repose of the wearied limbs without the renovation of sleep.

The exhaustion may be enduring in proportion to the intensity and endurance of the cause, modified by the temperament and resisting power of the patient. Or, again, it may be rapidly fatal where the conditions for renovation are absent or with-

drawn, as in hæmorrhage, and in some forms of injury the effects of which are not directly referrible to shock.

What is the proximate cause of nervous exhaustion? Probably an insufficient or ill-regulated supply of oxygenated blood to the nerve centres generally: but, except where blood is lost, it is not immediately apparent to what cause such inadequate supply is attributable. We know that the nutrient capillaries are controlled, through the small arteries, by the vaso-motor nerves; and it has been shown experimentally that interference with the nerve current towards the vessels causes their dilatation. But it would seem probable that these nerves influence the vessels otherwise than by stimulating their contraction, viz., by regulating the uniform or rhythmical distribution of the blood. Moreover, there is no doubt that there exists some agency by which the vaso-motor activity may be restrained,—by which, in other words, an inhibitory control over the contractility of the vessels is exercised. This must be in one of two ways,—either by the initiative agency of the brain, or by reflex action. The former mode is exemplified in the emotional act of blushing, or in the influence exercised over the *nervi erigentes*. In both these conditions the vaso-motor influence would seem to be suspended, or modified in such way as to allow of distension of the capillary vessels. If the effect be reflex, as in the early phenomena of inflammation, it would most probably be directly through an afferent and efferent nerve-channel, between the affected area and the source of nerve force, wherever that may be. But other movements, due to the ganglionic centres, may be influenced similarly in two ways. Peristalsis of the intestine may be stimulated by emotion, and the same effect may be produced by reflex irritation originating in the bowel. Yet it is singular that, in the act of blushing, we are supposing the vaso-motor nerves to be the conductors of an inhibitory mandate from the brain, whereas in the stimulation of the intestine we recognise an incitement to increased activity. Possibly the quickened peristalsis may be secondary, and directly due to augmented secretion, consequent on dilatation of the capillaries. Yet again, though the emotion of fear may produce copious perspiration, it is usually accompanied by pallor, which denotes arterial constriction. In truth, many of these phenomena are but ill-under-

stood, and require further elucidation; and this remark applies also to our present knowledge respecting the sources of vaso-motor influence, whether in stimulating contraction or for inhibition, regarding which the results of experiment and observation still leave much in obscurity.

It is probable that the cyclo-ganglia generally are originators of vaso-motor force, as well as similar sources in the medulla oblongata and other parts of the cerebro-spinal centre; but whatever may be the theory regarding the propagation of nerve energy, whether in harmonious or conflicting waves with corresponding results, or in other ways, it is impossible to attach any other than a negative meaning, *quoad* the result, to the term "inhibition," as the vessels can be dilated only by their relaxed condition permitting the blood to accumulate in them. Indeed, it is difficult to conceive how inhibition can be manifested save by a control exercised over the sources of active nerve force: *e.g.*, the cardiac branches of the pneumogastric must owe their inhibitory property to their power of suppressing the activity of the cardiac ganglia, which is probably their destination, and not to any direct control over the muscular structure of the heart. In like manner, as stimulation of the central end of the divided cardiac branch of the vagus produces dilatation of the abdominal vessels, we recognise a reflex inhibitory influence upon the semilunar ganglia through the medium of the splanchnics, as it ceases as soon as these last-named branches are divided; and the vaso-motor influence derived from the solar plexus is reasserted.

There are many conditions under which the vaso-motor government of the small arteries is modified, but at present it is impossible to classify them. That there is some correlation, in the exercise of control, between the cerebro-spinal and vaso-motor nerves must be admitted; and certain observed facts appear to point to the activity, in an inverse ratio, of the organic and animal nerve centres. Thus sleep, if dependent on constriction of the cerebral arteries, exemplifies this view; in like manner digestion, which is impeded by physical or mental exertion: and the compound act of respiration, does not negative the idea. In hypnation, the vaso-motor constriction, producing organic inactivity and sleep, is accompanied by absolute rest

of the muscular frame, except for the reduced form of respiration and circulation which then obtains; and these are under ganglionic influence. It is also reasonable to believe that any local demand for more or less active distribution of blood is responded to by the nerve centres which supply the area making the demand, and that fatigue or exhaustion may follow abnormal activity in these as in the cerebro-spinal system.

But what is more to the purpose in my present inquiry is the solution of the question, how any organ or tissue is prejudiced by suspended or altered control of the vaso-motor influence. The small arteries possess an intrinsic tone, and evidence of rhythmic variations in calibre, independent of nerve-influence or the heart's action; and their normal condition is that of a certain amount of constriction under the government of the vaso-motor system. Stimulation of this imparted tone implies a consequent excess of the normal state of contraction, and its suspension, more or less, is inhibition. Yet these axioms scarcely suffice to explain satisfactorily many of the phenomena which pathology presents for our notice; and it would seem safer, with our present knowledge, to fall back on the more general proposition, that the vaso-motor influence is exercised in regulating the uniform distribution of the blood. The loss of this important control must materially curtail the healthy tone of the vessels, notwithstanding their recuperative power after such privation: moreover, the normal blood-pressure would be diminished in any area so affected. The consequences of the above sources of disturbance would suffice to account for deterioration of organic function or of nutrition. Yet there may be another factor in the production of this result. Loss of tone in the small arteries is accompanied by an augmented flow of blood throughout any given area, and a rise in temperature. This would seem to indicate more rapid combustion; and, if unattended by any equivalent in the renewal of tissue, there would be consequent functional inactivity or textural degeneration. If the vaso-motor centres give way under a continuous strain on their activity, or from any other less direct cause, the organs they supply must suffer accordingly. No doubt some of the effects of exhaustion or over-stimulation of vaso-motor energy are witnessed in

atrophic and hypertrophic diseases; but the results may be apparent without organic change. The insomnia of the over-taxed brain of the too zealous student, and the sleepless mania and untiring restlessness of the drunkard are due, though for different reasons, to this vaso-motor exhaustion; and a similar explanation, *mutatis mutandis*, would account for the drowsiness of the sluggard. Degeneration in power of brain or muscle, from disuse, implies defective vaso-motor energy, consequent on restricted demand, and its necessary concomitant, insufficient blood supply.

I have said that nervous exhaustion is witnessed in various conditions of the body, and under different circumstances. A few instances will serve to exemplify these. A severe form of headache is accompanied by distension of the arteries of the scalp. Whether or not this vascular repletion is the cause of the suffering, it indicates suspended tone in the vessels affected, and is attended by disturbance in other parts of the circulation from deranged blood-pressure, as evinced by cold hands and feet, &c. Exertion under these circumstances prolongs the suffering; though alleviation is sometimes obtained by profuse perspiration: the dilated vessels are thus relieved, and the balance of the circulation is restored.

The effect of a rapid loss of blood is syncope, more or less complete. The proximate cause of this condition is nervous prostration, due to deprivation of blood in the nerve centres. This may be only transient, but it may also be fatal. If recovery follow, the effects of nervous exhaustion are often apparent for a protracted period, and manifest themselves in various forms of disturbance, according to the idiosyncrasy of the sufferer; and in some instances, where the loss of blood has been only moderate. An analogous condition is witnessed in copious and protracted suppuration. Prolonged and severe pain is also an exhaustive; and so likewise are attacks of acute localised inflammation, directly as well as indirectly. Many chronic diseases exhibit their exhaustive influence on the vaso-motor centres by the impoverished nutrition of the frame; and a similar effect is produced by the strain of protracted mental emotion. Privation of sufficient nutriment acts in the same way; and this, when conjoined with excessive exertion, either

physical or intellectual, often leaves an abiding effect on all the centres of nerve influence, in some cases inducing insanity.

In all the above-named conditions the value of repose and of plenty of oxygen and of ozone is recognised equally with that of nutritious and easily assimilated food. But the beneficial agency of stimulants, as such, is more than questionable; I believe that, except in extreme prostration, they are generally prejudicial.

There is, necessarily, a close alliance between nervous exhaustion and shock; but there is, at the same time, a distinction between them. Shock is the immediate effect of a suddenly operative cause, from which, if not fatal and there is no organic lesion, the nerve centres quickly rally; where there is organic lesion, as in ruptured viscus, the shock becomes merged in nervous prostration, which continues although local inflammation may supervene. That simple shock is sometimes immediately fatal there can be no reasonable doubt; but where such is the case, death is due to the strong impression on some of the nerve centres, not necessarily the brain. The symptoms described as characterising cerebral concussion are, to a great extent, attributable to shock. In like manner, a blow on the neck or in the epigastrium may destroy life instantaneously, by paralysing the cyclo-ganglia in these regions, either directly, or mediately through the reflex circle of the vagus, medulla oblongata and splanchnic nerves. Post-mortem appearances favour either interpretation; for the thoracic and abdominal viscera—especially the latter—are found loaded with blood, whilst the surface is blanched. The treatment, where time is allowed, should be directed to stimulating the medullary source of vaso-motor force, as well as to relaxing the constriction of the cutaneous vessels. In the collapse of cholera, resembling shock, the same condition of the abdominal vessels obtains, suggesting that the solar plexus is paralysed, probably through the intermediate influence of the vagus, by the poison; and that its elimination, if such it be, by the intestines, is the direct consequence of the accumulation of blood in their gorged vessels. What vaso-motor constrictor would stay this fatal flux? In the answer to this question we may find the means of tiding over the crisis of this unmanageable malady; but this must be by an appeal to the medulla oblongata.

It should be further remembered that nervous exhaustion is a condition favouring the assault or development of any disease, whether functional or organic, to which a patient may be prone. Illustrations of this are of daily occurrence in practice. Rheumatism, gout, ague, various forms of dyspepsia, &c., invade their predisposed victims when in a state of nervous exhaustion; and this after the lapse of a very long interval succeeding the primary attack. Even suppressed syphilis will again assert itself; and latent, or assumedly latent, organic disease, such as cancer and consumption, becomes developed under similar circumstances; perhaps especially so when the exhaustion which predisposes to such evolution is due to moral more than physical causes. The depressing influence of emotion, such as fear, in favouring the development of disease, is a familiar fact; it was exemplified, in very many instances, during the prevalence of cholera in this country.

It may be said that the preceding remarks merely embody that which is well known under a different title. This may be so: yet, if the interpretation of the facts be correct, something is gained by a recognition of the pathological relation between cause and effect. A more exact knowledge of the physiological cause of changes we witness in disease, and of their *modus operandi*, cannot fail to aid us in the treatment, both curatively and by anticipation of probable consequences.

There is one form of nervous exhaustion which would seem to be common—I had almost said fashionable—if we may judge by the frequency with which we hear it popularly quoted; yet I think it very doubtful whether this condition, viz., collapse of brain-energy from overwork, ever exists *per se*, i.e., so long as the ordinary rules of hygiene are not set at defiance. At any rate it is rare to hear the complaint coming from our deepest thinkers, our most prolific authors, our most diligent workers in science and literature. The fact is, that the condition attributed to brain-exhaustion is really due to general nervous prostration, consequent on inattention to the elementary laws of health. Close rooms, neglect of exercise, encroachment on the hours of rest, combined probably with irregular meals and recourse to the artificial stimulus of alcohol, are conjointly sufficient to produce the state I have been considering as exhaustion of the

vaso-motor centres. And it may be remarked that the moral influence of anxiety is a factor of no small importance in producing this result. I am informed that Dr Forbes Winslow once observed to a friend, that overwork of brain never alone produces insanity, but that anxiety and worry often do. The foregoing remarks apply with less force to the very young, of delicate and susceptible temperament.

Hysteria appears to be closely associated with primary disturbance of the vaso-motor nerve centres. Many of the anomalous symptoms it presents may be thus explained, without crediting the uterus with any agency in their production. That some other explanation than that of uterine derangement must be sought, in many instances, is apparent from the fact, now fully recognised, that the same train of symptoms which characterise the disease in the female may be present in the male; and it is time that this nomenclature should be replaced by a comprehensive word, etymologically correct, and more expressive of the real nature and extent of the disturbance, such as *Neuro-cachexia*.

Another form of nervous exhaustion, more commonly exaggerated and assumed than real, is that which is attributed to shock from railway accident. In most instances it seems to be now recognised that the theory of organic mischief to the spinal cord is rarely tenable, as an explanation of the condition in which the subjects of these accidents find themselves, after the immediate effects of the shaking to which they have been exposed have passed away. No doubt some of these cases are genuine, and the symptoms observed can be explained only by special derangement in the functions of the vaso-motor—indeed of all the cyclo-ganglionic—centres, either primary or consecutive. They are, usually, insomnolence or restlessness, confused dreaming, lack of appetite, dyspepsia, constipated bowels, general languor, with mental and physical disability. To these may be added other complaints, more directly referable to the cerebro-spinal centre, viz., local or general hyperæsthesia, numbness and formication, tenderness specially located at some part of the spinal column, imperfection of memory, eyesight, or hearing. In more serious cases there is cramp, defective sexual power, giddiness, and imperfect co-ordination of muscular action in walking. A

combination of many of the above symptoms is very suggestive of hysteria; and this circumstance renders it very difficult to attach a definite value to the complaints of patients. These cases are, in fact, so complicated by extraneous influences, that they require both patience and sagacity, aided by experience, to unravel them. The common practice is to enjoin absolute rest both of body and mind, together with a generous diet, tonics, and perhaps stimulants. The usual effect of such treatment is to aggravate many of the symptoms, by rendering the patient more dyspeptic and hypochondriacal, and by nursing the belief that serious illness exists, which the prospect of substantial pecuniary compensation naturally fosters. Leading questions elicit corresponding answers, and the imagination is thus brought into play. Moreover, all the usual subjective symptoms which are required to make up a case are now so popularly known, that designing patients, especially of the neuro-cachectic type, have no difficulty in satisfying themselves, whilst they impose even upon their medical attendants. In this way it is that the medical evidence in these cases is so often contradictory, and both judge and jury are perplexed if not misled; the ends of justice being thus thwarted by the impossibility of proving the knavery of a dishonest claimant.

Instances are not uncommon of collapse, rather than exhaustion, of brain-force, from disuse of the organ. This is witnessed in those who abruptly withdraw from a busy, active life, which had yielded but little variety except in the degree of excitement their calling may have afforded, and whose limited resources outside their occupation supply no substitute when that calling is laid aside. How many there are whose lives are abridged by such sudden change of habits, when they have not the power or the will to accommodate themselves to their circumstances by adopting fresh employment: a sad sequel to years of unremitting toil. The mental prostration to which I refer may endure for a considerable time without much variation; but it is more commonly progressive, and may involve loss of memory and other faculties, or terminate in imbecility and death. In some instances these stages are passed through much more rapidly than in others. What is the rationale of this condition, pathologically considered? It appears to me that it is probably

attributable to the sudden and complete withdrawal of the wonted stimulus to the vaso-motor nerves supplying the cerebral arteries; whereby the brain, previously well nourished, becomes impoverished, and its functions are impaired and gradually lost. The physical change of the brain, misnamed softening, would be included in this category, and may be explained in the same way by the deteriorated function of the vaso-motor nerves, in the regulated distribution of oxygenated blood. The brain ceases to solicit its wonted supply, and is consequently enfeebled and starved.

It is difficult to exhaust such a subject as the present, from which so few pathological changes can be excluded. Certainly all conditions which involve localised quantitative changes in the circulation must be included. The phenomena of congestion, simple hyperæmia and inflammation must be studied by the light of the vaso-motor influence. The agency of stimulants in promoting granulation may be accounted for by the demand which is thus made on these nutrient nerve centres; and so likewise the beneficial effect of local blood-letting and of counter-irritants.

There are, also, many other circumstances, in which exaltation of function may be explained by excessive activity of the nutrient vessels, implying a corresponding condition of the vaso-motor nerves. This may occur in a particular set of muscles, or in some part of the cerebro-spinal centre, or in any of the glands, such functional exaltation, whether from choice or necessity, inviting a regulated increase in the supply of blood; and this appeal is responded to by the vaso-motor centres, and the required impulse is conveyed through the efferent nerves. In this way either augmented functional activity or textural hypertrophy may be produced. Curable forms of insanity are probably attributable to this localised functional activity, for which diversion of the mind to other subjects of thought and occupation has been found so efficacious a remedy. Many organic pathological changes, atrophic as well as hypertrophic, admit of a similar interpretation; and there are but few functional disorders which are not indirectly associated with, if not actually dependent on, the agency of the vaso-motor nerve centres. It is unnecessary to pursue this branch of the sub-

ject further, as light has been thrown on many of the conditions referred to by various experimental physiologists and pathologists.

In the treatment of nervous exhaustion it is of course essential to ascertain its real cause, whether physical or moral, proximate or remote, with a view to control its influence, or, if possible, to remove the patient from the sphere of its operation. A rational view of the actual condition must likewise be studied, in order to avoid the indiscriminate, and often senseless use of remedies, which are supposed to be appropriate in debility, loss of flesh, and lack of appetite. High feeding, stimulants and tonics are popularly credited with the character of specifics in such cases; yet they are often prejudicial, and in some cases seriously so. We do more good by supplying some element which is deficient in the system, or by correcting some defect in the organic chemistry of assimilation, or removing some source of irritation. Many selected articles of food fulfil these conditions; other desiderata are realised medicinally by such agents as the mineral acids, quinine, soluble forms of iron, the salts of potash, especially the chlorate, and other preparations which possess a special reputation as nerve tonics. If these are largely diluted, absorption is more certainly secured, and irritation is averted. Dietetic study, combined with regularity in food and exercise, are of course essential.

Although the importance of avoiding all sources of exhaustion, especially in severe injuries or operations, is self-evident, it is not always sufficiently insisted on. The depression succeeding even temporary excitement or exertion, in an enfeebled and susceptible frame, is often followed by an apparently disproportionate degree of exhaustion, which may seriously endanger the patient's life. A more accurate recognition of the physiological cause of this result should secure a more scrupulous attention to the necessary precautions in these circumstances. We watch and guard against the effects of abnormal excitement in the reaction following shock; but the exhaustion consequent on ill-timed excitement is more often productive of mischief, though its cause may be unknown to or not guarded against by the medical attendant.

In attempting an explanation of certain pathological changes

and the action of therapeutic agents, it is desirable to review the ground on which we stand.

1. I assume that the normal tone of the arteries may be augmented or diminished within limited bounds, without such variation constituting a deviation from the standard of health, unless unduly prolonged.

Beyond such limit of intensity and duration, either functional or organic derangement, atrophy, or hypertrophy result.

2. That persistent constriction or dilatation of the small arteries is equally the cause of mal-nutrition; in the former case by limiting the quantity of blood circulating in the affected area, in the latter by the overcrowding of the vessels and the excess of carbonic acid evolved in the capillaries.

3. That the contraction of arteries when normal is intrinsically rhythmical, but that abnormally it may become intermittingly or continuously spasmodic, or it may be restrained or wholly suspended.

4. That capillary obstruction, when it exists as a primary condition—as easily seen in the web of a frog's foot when irritated—is due to a disturbance of the vital correlation between the blood and its channels; but it is very questionable whether capillary congestion is the consequence of arterial constriction, though it may produce it, or that the accumulation of dark blood in the capillaries, from whatever cause, implies arterial tension.

These considerations refer chiefly to the physical control exercised by the vaso-motor nerves; but their far-reaching influence in the realms of organic life may include biological consequences, with which our present knowledge has not made us acquainted.

Variations in the temperature of the body occur under various circumstances. In most instances there is an intelligible explanation of these deviations from a healthy standard, but for some no satisfactory reason can be assigned. Whatever may be the ultimate cause of a rise or fall in temperature, there can be no reasonable doubt that a change in the vascular tension, due to the vaso-motor influence, is the proximate agency by which these changes are produced. Symptomatic fever, of whatever type, is characterised by a rapid and vigorous circulation, and

consequently quickened respiration. The evolution of heat is, therefore, more abundant in the capillaries. In the cold stage of intermittent this state is reversed. In very high temperature—and I have known it rise to 110° —the evidence of nervous perturbation and excitement is always more pronounced, which is both the cause and the consequence of a loss of balance in the circulation, that together place life in imminent peril. Functional derangement, involving the nervous centres, may cause a rise in temperature of several degrees, and prove as transient as the cause. It is interesting to notice how small patches of congestion appear on the surface and fade without any apparent cause. This must be produced by the suspension of vaso-motor influence in the limited areas so affected. In the absence of capillary obstruction the thermometer is a gauge of the rhythmic activity of the arteries, and therefore of the vaso-motor centres.

The contrast between what may be called (to use somewhat obsolete terms) healthy and unhealthy inflammation, is an interesting study, for whatever may be the theory founded on any particular definition of that word, there is no doubt that practically there are conditions presenting all the sensible phenomena of inflammation which tend, some to repair and others to destruction. The advancing condition of the affected areas is very different in these several circumstances, apart from their intrinsic vitality or the state of the blood circulating in them. In the destructive process, the primary dilatation of the small arteries is augmented and perpetuated. The vaso-motor action is suspended, and the blocked capillaries and their contents die, the early increased flow of blood to the part simply accelerating this result. But in reparative inflammation the vaso-motor control is reasserted, fresh channels are developed for the blood to flow into, and the abundant material is utilised. Ulceration, abscess, phagedena, exemplify these conditions in their earlier and later stages. In senile gangrene the intrinsic tone of the arteries, as well as that derived from the vaso-motor nerves, is extinguished, and thence the loss of vitality. The influence of a powerful stimulant, such as nitric acid, in arresting rapidly spreading ulceration, must be due to the strong appeal made to the nutrient nerve centres. It would be fruitless to invoke such an effort in a limb, of

which the arteries are rigid tubes. A transient state of congestion, which is not dependent on venous obstruction, is but a modification or arrested evolution of inflammation, and may be explained in the same way. This is often witnessed in these affections of the lungs; and the suggested explanation may account for the anomaly which a comparison between the former and modern treatment of pneumonia offers. Venesection was a rough and ready method of restoring the disturbed equilibrium of the circulation, leaving the patient, if saved, to struggle back to health as best he might. More trust is now placed in nature's recuperative power; and stimulants, with counter irritation, aid the vaso-motor power to re-establish the lost balance without depletion.

The effect of blood-letting or counter irritation may be partly ascribed to the relief afforded to the local vascular repletion; but probably chiefly so, especially in the use of the latter remedy, to the stimulus thus imparted to the vaso-motor centres. The abstraction of blood tends, no doubt, in some instances, materially to rectify the disordered blood-pressure.

Surgeons are familiar with the value of both heat and cold in the treatment of local inflammation. Where there is evidence of much congestion, warmth and moisture are preferable; but in other cases the continuous—not intermittent—employment of cold applications is generally more eligible. How does this "blowing hot and cold" for the same end admit of explanation? A cold application stimulates contraction of the small arteries, and thus diminishes the quantity of blood in the affected area. Where moist warmth is used the relief is more directly mechanical. The tissues themselves are relaxed, and exudation is encouraged, as well as cutaneous secretion. The patient's feelings are often the best guide to the surgeon in making his election between the two in doubtful cases.

The shock consequent on severe burn or scald, when not fatal, is often very enduring, and involves the vaso-motor system extensively. No doubt the serious derangement in the blood-pressure is instrumental in producing the collapse, and in favouring the subsequent development of inflammatory attacks of the mucous membranes.

Exposure to a sufficiently low temperature for a long time produces pallor of the skin and rigidity of the muscles farthest

removed from the heart. This is accompanied by numbness and succeeded by torpor, terminating in coma and death. The symptoms which usher in the fatal result very closely resemble those which characterise poisoning by alcohol or a narcotic; and are apparently attributable to the same proximate cause, viz., the accumulation of dark blood in the brain, and, consequent thereon, the gradually declining sensibility of the lungs to the presence of carbonic acid. The pallor and muscular rigidity must be due to the exclusion of blood from the capillaries of the skin and of the muscles; and this, in turn, is dependent, at least in part, on the extreme contraction of the small arteries, under the appeal to the vaso-motor influence. The feeble generation and unequal distribution of animal heat, under these circumstances, together with the abnormal vascular tension, must aggravate the condition and hasten the fatal result. The chief appearance noticed, *post-mortem*, is much congestion of the internal organs, especially the brain. The invigorating effect of moderate cold is a response to the healthy stimulation of the vaso-motor nerves.

The poisonous action of *Alcohol* is expended chiefly on the brain and lungs, which in fatal cases are found deeply congested. This result is such as might be anticipated, from the pneumogastric being the centripetal nerve, and the centre of the reflected vaso-motor nerve influence being the medulla oblongata. When the dose is large the effect is very rapid. One instance came under my own notice in which the victim sucked spirit from a cask till he dropped, and was brought to the hospital in a state of profound coma, surviving only a short time. The exhilaration produced by a moderate quantity of alcohol is due, at any rate in some measure, to stimulation of the vaso-motor centres, and this is especially noticeable where there has been previous exhaustion. But when more is taken, the exaltation of brain function passes into the stage of delirium and loss of co-ordinating power, and thence to stupor. This is quite consistent with the *post-mortem* appearance in fatal cases, and indicates the gradual suspension of vaso-motor control, and the accumulation of dark blood in the dilated capillaries, which the sluggish circulation in the pulmonary vessels and the feeble respiration favour. The habitual and free use of alcohol, by constant

stimulation, enervates the vaso-motor energy and enfeebles assimilation, inducing, in combination with other causes, disease in organs which are compelled to exert abnormal activity to eliminate the poison and maintain the circulation.

In comparing the effects of alcohol with those of extreme cold, we remark that congestion of the brain and insensibility of the lungs to the presence of carbonic acid are the proximate cause of death in both; but this condition is in each instance brought about in a different way. In poisoning by alcohol and its allies, there seems to be gradual withdrawal of vaso-motor influence, and consequently a congested state from dilated vessels: but the action of cold causes constriction of the vessels on the surface and in the limbs, and thus compels or permits the blood to accumulate in the internal organs, the vessels of which yield to the pressure, and become dilated and obstructed from stasis.

Chloral and *Ether* may be placed in the same category with alcohol, the *post-mortem* examination revealing the same cerebral congestion.

As regards *Chloroform*, when administered by inhalation, it has appeared to me that its deadly influence is, in some cases, negative rather than positive; that its fatality is the consequence of the exclusion of atmospheric air, rather than attributable to the direct impression of the vapour on the nerve centres; unless, indeed, there be some peculiarity in the condition of the patients, from disease or otherwise, which renders them especially susceptible of the poison. That death from this drug may occur from simple apnoea was demonstrated in a case which came under my own observation some years since. I had removed a mammary tumour from an apparently healthy woman of about 35, under chloroform. The wound was dressed and the patient was sleeping quietly, when I observed that she ceased to breathe, though the heart continued to beat. After considerable perseverance, using Marshall Hall's method, natural respiration was restored, and a stimulant was given. But she soon relapsed into the previous condition; and this occurred repeatedly for the space of an hour and a half at least, the same method of resuscitation being resorted to on each occasion; she then recovered. In this case either the reflex action of the phrenic nerves must have been inhibited, or the susceptibility of the lungs to the

presence of carbonic acid must have been suspended. Fortunately the heart's beat was not interrupted. The intoxication caused by inhaled chloroform often resembles that of imbibed alcohol, in its progressive stages to transient coma. In some instances they cause death in the same way, by producing congestion of the brain and lungs, as manifested during life and after death; but there can be no doubt that the fatality of chloroform is more often due to its reflex inhibitory impression upon the heart,—the pneumogastric being, in that case, both the afferent and efferent medium of communication.

Opium and other allied narcotics act by paralysing the vaso-motor and respiratory centres; and the fatal stupor and tendency to apnœa can be averted only by rousing the patient to voluntary acts of respiration.

The active principle of *tobacco* produces its deadly effect in the same way, congestion of the brain and lungs being the most noticeable *post-mortem* appearance.

As the intestines are under the control of the ganglionic nerves, the action of *aperients* would appear to be due to the appeal which is made to the ganglionic centres. Some laxative drugs stimulate the peristaltic movement; others act by increasing the secretion of the mucous surface, which is determined by the augmented local activity of the circulation. The reflex action of many drugs on the intestines may be thus interpreted; the value of opium in controlling diarrhœa, and in relaxing spasm in constipation, may be explained by its influence over the vaso-motor and musculo-motor nerves.

Tea—especially green tea—and *coffee* stimulate the flagging vaso-motor activity; in this way they are beneficial in headache accompanied by dilated arteries. *Guarana* acts in a similar way. This action of coffee is exemplified in narcotic poisoning. The wakefulness produced in some people by the two above-named beverages must be due, I presume, to the increased activity of the circulation in the brain which they occasion; the stimulus, in health, being insufficient to cause that degree of contraction of the cerebral arteries which is supposed to induce sleep. *Nitrate of amyl* causes dilatation, by subduing the vaso-motor energy.

The action of *digitalis* on the heart would seem to indicate a special control over the vaso-motor ganglia which supply this

organ. Possibly, however, the influence of this drug may be more general; and it may be that its power of moderating the heart's action is due to the more uniform and regulated distribution of the blood-pressure. By controlling the abnormal activity of the vaso-motor system, and thus regulating the blood-pressure, the beneficial effect of digitalis in large doses, in drunken delirium, admits of an explanation, if this hypothesis be conceded.

The *modus operandi* of *mercury* and *iodine* in stimulating absorption is an open question. It may be through the blood-vessels or through the lymphatics. The former solution seems to be more consistent with our present knowledge on the subject. By controlling the nutrition of a given area, structural growth may be encouraged, or waste of texture favoured, without any necessary interference with the normal activity of the absorbents; indeed, we have no reason, physiologically, to regard the lymphatics as other than passive tubes under the government of physical laws. Pressure promotes absorption, chiefly by abridging the nutrition of the area pressed upon.

It would not be difficult to multiply instances of the assumed influence of drugs over the vaso-motor system of nerves. That their action would vary under different circumstances, and with the existing condition of the nerve centres, whether normal or disturbed, is to be expected; and thus some apparent contradictions may be reconciled by reflection and observation. I would, however, in concluding these observations, guard myself against the imputation of assuming to enunciate what is new and has not been already discussed by pathologists as well as physiologists, or of intending to attribute all I have described exclusively to vaso-motor disturbance. "*Qui nimium probat, nihil probat.*" The functional relations which pervade organic life, and which are especially obvious in the interdependence of the various nerve centres, forbid any such rash assertion. My purpose has been to indicate suggestively, and to adduce familiar instances of, the important control which the vaso-motor system exercises in the manifestation of various pathological phenomena, as well as in the cure of disease. I venture to think that a more general recognition of this fact, and the study of therapeutics in the light it seems to afford, may enable us to explain some things we already know empirically, and also help to place the medicinal treatment of disease on a more scientific basis.

THE DEVELOPMENT OF THE GREAT OMENTUM AND
TRANSVERSE MESOCOLON. By C. B. LOCKWOOD,
F.R.C.S. Lond.

BEFORE the development of the intestines and peritoneum was seriously studied, the relation of the great omentum to the transverse colon was fairly easy to understand. It was usually acknowledged that the following account was true.¹ Beginning as the greater curvature of the stomach two layers of peritoneum are seen descending; one layer passes from the front of the stomach, the other from the back, and they meet below to form the great omentum. Continuing downwards towards the lower



FIG. 1.—s, stomach; o, omentum; c, colon; mc, mesocolon; m, mesentery.

part of the abdomen, at last the two layers loop upwards to run towards the spine. Before the spine is reached the two layers separate to embrace the transverse colon. It therefore follows that the colon is fastened to the back of the abdomen by two layers of peritoneum, which are called the mesocolon. A glance at the diagram will at once make clear the description (fig. 1).

¹ Quain's *Anatomy*, 9th edition, vol. ii. p. 729 *et seq.*, is taken as the basis of this account.

Owing to the researches of Haller into the development of the intestines, it has been thought necessary to modify the old tracings in the following way:—As far as concerns the arrangement of the two layers of peritoneum which extend from the great curve of the stomach to the transverse colon no change is made. The transverse mesocolon is quite different: it is said to consist of four layers instead of two (fig. 2).

A short statement of the mode of formation of the great omentum and of the development of the transverse colon will show the reason for this new departure. The origin of the omentum may be first considered. At an early stage of development the stomach is attached to the back of the abdomen by two layers

FIG. 2.—s, stomach ; c, colon.

Note.—For the sake of clearness the layers of peritoneum forming the transverse mesocolon are drawn some distance apart. They are really supposed to be adherent.

of peritoneum ; these layers form a mesentery for the organ, and are therefore called the mesogastrium (fig. 3). The mesogastrium extends from the spine to the greater curvature of the stomach, and, continuing to grow in a disproportionate manner, it forms a fold. This fold of the mesogastrium consists of two layers of peritoneum ; it loops downwards from the stomach towards the lower part of the abdomen ; it then ascends to the spine. In fact, the mesogastrium has become the great omentum (fig. 4). It only requires that the transverse colon be placed between the layers of peritoneum which ascend towards the spine, entirely to reproduce the old description of the omentum

and mesocolon. If the development of the transverse colon be next examined it will be seen that this appears almost impossible to occur.

Stated briefly, it may be said that at first the colon is straight. The lower end of the gut is fixed in the pelvis, the upper ends at the cæcum, which is placed almost in the centre of the abdomen. In common with all the rest of the alimentary canal, it has an extensive mesentery. As the colon grows in length, the position of the cæcum alters. It passes round the upper part of the abdomen, so that to begin with it is beneath the stomach, thence

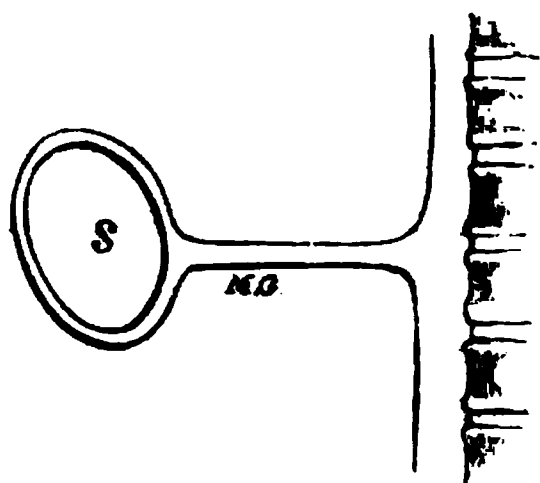


FIG. 3.—From Cruvelhier, *Traité d'Anatomie Descriptive*, vol. ii. p. 550. s, stomach; mg, meso-gastrium.

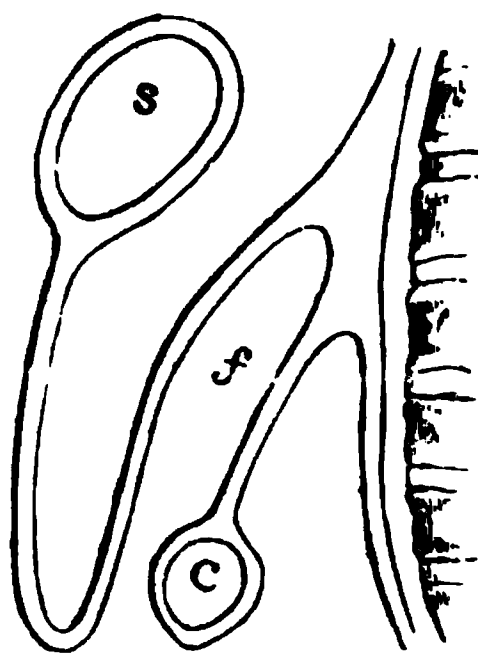


FIG. 4.—s, stomach; c, colon; f, fossa.

it passes across to the right side, and afterwards it descends into the right iliac region. From this it follows that at first only the left colon exists, afterwards the left and transverse colons, and at last a left, a transverse, and a right. Until quite a late stage of development the whole of the colon is attached to the back of the abdomen by a considerable mesentery. The transverse colon is the part more particularly in question. It is fastened to the spine by its mesentery just below the place where the meso-gastrium is attached (fig. 4). If the loop of the omentum were made longer, and if the mesocolon became fastened to the under surface of the omentum, the arrangement described in the new account (fig. 2) would be exactly reproduced. Indeed, this is what Haller and other observers believe to happen, and this is why the transverse mesocolon is said to be made of four layers

of peritoneum, two belonging to the omentum and two to the mesocolon.

Certain reasons can be found which tend to show that this theory, which in the remainder of this paper will be called Haller's theory, may not be true. Haller says that the upper surface of the mesocolon and the under surface of the omentum become adherent. It is an unusual thing for serous surfaces to become adherent even during the course of development.¹ It may reasonably be asked why the process of adhesion limits itself to this particular part of the peritoneum? A still more weighty reason for disbelief in Haller's theory would be, that the old account of the relation of the peritoneum to the transverse colon appears to be true (fig. 1). A number of bodies have been examined in the dissecting-rooms of St Bartholomew's Hospital: the peritoneum, which forms the under layer of the great omentum, always seemed to pass underneath the transverse colon to get to the spine. In other words, the colon was always between the two ascending layers of the great omentum.

It has been asserted that in the foetus the two ascending layers of the omentum are capable of being stripped off the transverse colon and mesocolon (J. F. Meckel, J. Müller, Hansen, and Huschke). Evidently if this were done the original state of affairs (fig. 4) would be restored. The attempt has been made upon several foetuses, and has never succeeded without laceration of the serous membrane, which, it may be remarked, is exceedingly thin and delicate. It is significant that, until Haller invented his theory, the old account of the mesocolon was thought to be true; it was only discovered to have four layers after the adhesion theory had been originated.

Starting on the assumption that the colon is in reality between the ascending layers of the great omentum, and that the transverse mesocolon consists of only two layers of peritoneum, a great many embryos (human) have been examined in order to endeavour to explain how the change occurs; the change being this, that the colon loses its mesentery (fig. 4) and gets between the layers of the omentum (fig. 1). In embryos an inch and a half long, and somewhere about the tenth week of intra-uterine life, it was found that the cæcum had passed round the abdomen

¹ See also Cleland, *Journ. of Anat. and Phys.*, 1868, p. 104.

as far as the right side. These embryos therefore possess a left and a transverse colon. Both of these portions of the gut have a considerable mesentery. The great omentum may be seen without difficulty close to the greater curvature of the stomach. Its posterior or ascending layers pass back direct to the spine. It seems unnecessary to say that at present they have no connection with the transverse colon. The under layer of the omentum, after reaching the spine, turns down again to become continuous with the upper layer of the transverse mesocolon (fig. 4). It has been remarked that at this period the mesocolon exactly resembles the mesentery of the small intestines. A deep peritoneal fossa therefore exists between the

FIG. 5.—s, stomach; c, colon; f, peritoneal fossa; v, vertebral column.

under surface of the omentum and upper surface of the transverse mesocolon. The importance of this fossa is very great, as it will be seen later on that most interesting changes occur in its walls; it is the point towards which attention should be especially directed.

Embryos of a larger size, $2\frac{1}{2}$ inches long, and probably between the third and fourth months of intra-uterine life, were next examined. A considerable change has occurred in the relations of the great omentum and transverse mesocolon. The former is still seen hanging from the greater curvature of the stomach; it has increased in length, but not very much. The posterior or ascending layer can no longer be traced back to the spine. It extends a short distance towards the posterior wall of the

abdomen, and then turns forwards to become continuous with the superior layer of the mesocolon. From this it follows that the superior layer of the mesocolon no longer reaches the spine (fig. 5).

The inferior layer of the transverse mesocolon presents no peculiarity, but merely passes from the under surface of the mesocolon back to the vertebral column. It is evident that the mesocolon has lost a part of its superior layer of peritoneum. In embryos nearly $3\frac{1}{2}$ inches long, and apparently between the fourth and fifth months of gestation, further changes have taken place. The great omentum has increased very little in length. It is still placed immediately beneath the curve of the stomach,

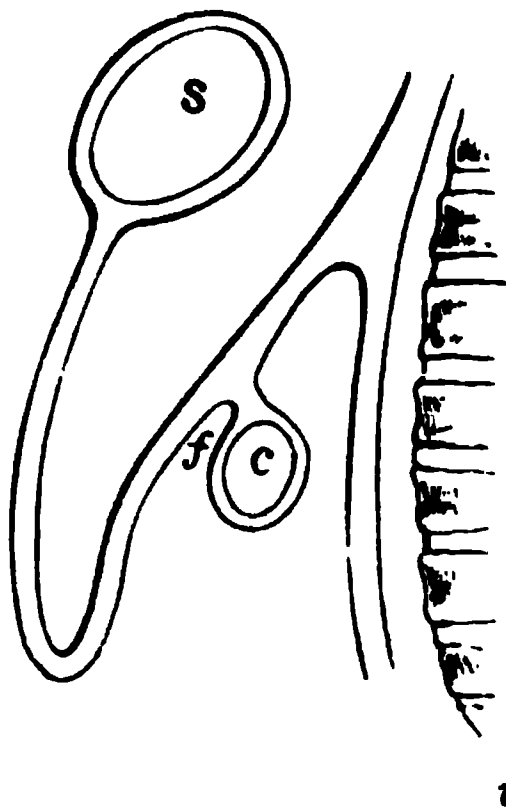


FIG. 6.—s, stomach ; c, colon ; v, vertebral column ; f, fossa.

and considerably above the transverse colon. There is no evidence that any process of adhesion is taking place. Indeed, the colon and omentum are quite apart. A very great change has nevertheless occurred. The ascending or posterior layer of the great omentum only extends a very short way towards the spine (fig. 6), and then turns downwards again over the colon. This brings about that the peritoneal fossa between the under surface of the omentum and upper surface of the transverse mesocolon has almost disappeared. It further happens that the colon is almost between the ascending layers of the great omentum and has lost its mesentery.

In larger embryos the small fossa, seen in fig. 6, quite disappears, and when this has occurred the peritoneum has the

arrangement formerly described, viz., that as the ascending layers of the great omentum ran back to the spine they formed the transverse mesocolon, which, therefore, consisted of only two layers. It may be remarked that the fossa within the omentum and mesocolon persists longest towards the left side. In embryos and foetuses the stomach is much more vertical than in the adult. From this it follows that the colon is nearer the pyloric than the cardiac end of the organ. The omental fossa is therefore wider towards the cardiac end, and takes longer to become obliterated.

If these observations are correct, it seems quite possible for the transverse colon to become closely related to the omentum without the intervention of any process of adhesion. Merely the withdrawing of the fold of peritoneum between the under surface of the omentum and upper surface of the mesocolon is sufficient to bring this result to pass; and more, for it at once places the transverse colon between the layers of the omentum. It still remains to be discussed how the fossa becomes obliterated, how the peritoneum which forms it gets drawn out. It would be a simple explanation to say that the peritoneum forming the fossa has been pulled out by the growth of the great omentum—in fact, that the serous membrane forming the fossa has now to form part of the omentum. This may be partially true, but an examination of many embryos shows that, as a rule, the omentum does not grow very much before birth. Its increase in size does not seem large enough to remove all the serous membrane forming the fossa. The growth of the colon itself may be a factor. About the time the fossa is being removed the colon is increasing in size. In the youngest embryos there is no distinction between large and small gut as far as calibre is concerned. As growth progresses the colon becomes a receptacle for meconium, and its proportionate size is very great. It does not seem hard to believe that this increase may be one of the forces at work in the removal of the peritoneum forming the fossa.

It follows from the above account that,—

- A. The old account of the mesocolon is true. That it contains two layers of serous membrane, not four.

B. That adhesion does not take place between the omentum and transverse mesocolon.

C. That the peritoneal fossa between the omentum and transverse mesocolon becomes obliterated by an unfolding of the serous membrane.

Specimens illustrating this account have been placed in the Museum of St Bartholomew's Hospital.

NOTES ON TWO INSTANCES OF ABNORMALITY IN
THE COURSE AND DISTRIBUTION OF THE
RADIAL ARTERY. By ARTHUR THOMSON, M.B., *Senior
Demonstrator of Anatomy, University of Edinburgh.*

THE first of these conditions consisted of a low division of the brachial artery into radial and ulnar. The radial was of small size, and was joined near the wrist by the anterior interosseous, which formed the channel through which the blood passed to those portions of the hand usually supplied by the radial. Curiously enough, this condition existed in both arms of the same subject, though in one instance the slender representative of the radial artery had been missed by the dissectors. The brachial artery passed down in front of the elbow until it reached a point three inches below the level of the internal condyle. At this point, as it lay under cover of the pronator radii teres, the artery divided into the ulnar and a trunk common to the anterior interosseous, posterior interosseous, and abnormal radial.

At the point at which the artery usually divides into radial and ulnar, we found arising from its outer side a branch which in course and distribution corresponded to the recurrent radial artery.

The subsequent course of the ulnar artery was normal.

The other trunk, which in position and source of origin corresponded to the common interosseous artery, remained undivided for about one-eighth of an inch; it then broke up into—

- (1.) Posterior interosseous.
- (2.) Anterior interosseous.
- (3.) Trunk giving origin to the radial.

The two former were normal in position.

With regard to the latter, it was traced down for an inch in company with the median nerve beneath the pronator radii teres. At this point it gave off a branch which was of small size, the *cormes nervi mediani*. This branch was subsequently lost in the substance of the flexor sublimis digitorum. After giving off this branch the radial artery passed toward the outer side of the fore-arm, concealed by the pronator radii teres under

cover of the radial head of origin of the flexor sublimis digitorum, and resting on the flexor longus pollicis, just inferior to the insertion of the pronator radii teres the artery became superficial, and lay between the tendons of the supinator longus and flexor carpi radialis.

The artery was, however, very small, and quite insufficient for the supply of those parts to which it is usually distributed, hence its subsequent course was followed with interest.

Close to the lower border of the pronator quadratus the diminutive radial, as it lay between the tendons of the supinator longus and flexor carpi radialis, was joined by an artery of the calibre of the normal radial.

This artery was traced inward along the lower border of the pronator quadratus under cover of the tendons of the flexor carpi radialis, flexor longus pollicis, and flexor profundus digitorum, and was found to be continuous with the anterior offset of the anterior interosseous artery beneath the pronator quadratus.

The radial artery augmented by its junction with this branch, which is to be regarded merely as an enlargement of the anastomoses between the anterior radial carpal branch and the branches from the anterior interosseous, then gave origin to the superficialis volæ, which was of small size and appeared like a direct continuation of the slender radial. In other respects the distribution was normal, the combined artery passing round the wrist and following the course of a normal radial.

A precisely similar condition existed in the opposite arm of the same subject, though the slender radial had not been traced to its junction with the anterior interosseous at the wrist.

The instances on record of this condition are not very numerous, especially such a condition as the foregoing, where, in addition to the radial being augmented at the wrist by the anterior interosseous, the radial itself arose at an abnormally low point in the fore-arm.

Instances of low origin of the radial are recorded in "Quain," (pl. xxxv. fig. 4), and in Henle (*Handbuch der Gefäßlehre*, p. 270), who quotes a number of instances. In the example figured by Quain (pl. xxxv. fig. 4) the method of origin and course of the artery was much the same as that recorded in the present in-

stance, with this difference, however, that in Quain's case the artery was of considerable size, and was joined at the lower border of the pronator radii teres by a vas aberrans.

Quain, in pl. xliv. fig. 1, figures a case of the anterior interosseous compensating the slender radial at the wrist, but in this example the radial was derived from the axillary artery.

Henle describes the condition in which the radial may be augmented at the wrist by a branch from the anterior interosseous, which may either pass superficial to or beneath the pronator quadratus, and quotes "Tiedemann" (pl. xlv. fig. 3).

- α , abnormal radial artery ;
- bb , anterior interosseous ;
- c , trunk common to interosseous, radial, and median branches ;
- d , median artery ;
- e , posterior interosseous artery ;
- f , recurrent radial ;
- g , brachial,
- h , ulnar, and
- i , superficial volar arteries.

Case II.—In the second instance which we propose recording, the radial artery was seen to be joined by an offset of the anterior interosseous, precisely similar to that described in the foregoing notes. Here, however, the offset of the anterior interosseous was of small size, and its interest entirely depended upon the explanation which it afforded of the previous condition,

which undoubtedly merely consisted of an enlargement of this channel of anastomosis. In its subsequent course and distribution the radial varied much from the normal. Reaching the interval between the bases of the metacarpal bones of the thumb and index, the artery split up into three branches; of these two were large and of equal size. The third, much smaller, was the metacarpal branch, and supplied the dorsal aspect of the second and third interosseous spaces.

Of the remaining two trunks one followed the normal course by passing between the two heads of the abductor indicis, previous to which it gave off the dorsalis indicis. Tracing this artery onward, we found it normal in position but abnormal in the distribution of its branches. Thus, as it lay under cover of the inner head of the flexor brevis pollicis, it gave off a branch of considerable size, which crossed the metacarpal bone of the index finger beneath the adductor pollicis, and terminated on the *ulnar* side of that digit; in addition, as the artery lay deeply in the palm, forming the deep arch, it gave off four palmar interosseous branches.

Passing back to the other branch into which the radial divided, it was traced over the dorsal aspect of the origin of the abductor indicis from the metacarpal of the thumb. Reaching the distal border of that attachment, it lay upon the dorsal surface of the inner portion of the flexor brevis pollicis, the fibres of which it immediately pierced, appearing anteriorly close to the head of the metacarpal bone of the thumb, under cover of the attachment of the adductor and flexor brevis pollicis. Here the artery split up into branches, one of which passed to the ulnar side of the pollex, the other crossed the palmar aspect of the adductor and inner attachment of the flexor brevis pollicis close to their insertion, communicated with the superficial palmar arch, and terminated by supplying the radial side of the index finger.

The radial side of the thumb was supplied by a branch from the superficialis volæ.

The superficialis volæ was of large size, and completed the superficial arch from which the digital arteries arose quite normally, that supplying the ulnar side of the index joining the branch already described as being derived from the radial.

The instances of abnormality in the distribution of the digital

arteries are so numerous that their analysis is difficult. Fig. 2, plate xl, "Quain," approaches more nearly to the description given above, especially in regard to the origin of the digital branches to the thumb and ulnar side of the index finger, but differs in the formation of the other palmar digital branches which are in part derived from the ulnar, in part from the median artery in the hand. In the present instance, these were derived from the superficial palmar arch, which in formation and position was normal.

THE CAUSE OF THE FIRST SOUND OF THE HEART
AND THE MODE OF ACTION OF THE CARDIAC
MUSCLE. By JAMES W. BARRETT, M.B. (MELBOURNE),
M.R.C.S.E, *Fellow of the Royal Colonial Institute.*

As a visitor to England the conflict of opinion on these subjects has proved so exceedingly confusing to me that I desire through the medium of this *Journal* to draw attention to some original experiments performed by Professor Halford of Melbourne some twenty-five years ago, which throw considerable light on the subject. I may add that I have had the honour to repeat and somewhat modify these experiments at frequent intervals since 1877.

(A.) *The Cause of the First Sound.*

This is allowed by most observers to be due either to the auriculo-ventricular valves or to the contraction of the ventricular muscle, and the matter resolves itself into a determination of the relative merits of these two suppositions.

If it is caused by the valves, it is not due to the closure of the valves, since, in the first place, their closure would cause a short sharp sound like the second; and, further, they are closed before ventricular contraction begins. This may be shown by the following experiment:—

From a relaxed heart (man) the upper part is cut off by a horizontal incision through the auricles just above the level of the auriculo-ventricular valves. The aorta and pulmonary artery are ligatured and the ventricular portion put in a cup with the apex downward. Fluid is now driven, by means of a syringe, through the auriculo-ventricular orifice, care being taken to use only very moderate force. As soon as the ventricle is filled the valves close.

Here the ligature represents the semilunar valves closed from arterial tension, the syringe represents the auricular contraction, and the distension of the ventricle represents the “loading” of the ventricular muscle, which occurs normally, and by which

the elasticity of the ventricle is called into play, and pressure is exerted on the blood, and so closure of the auriculo-ventricular valves effected. If, then, it is due to these valves, it is caused by their vibration and not by their closure, since that occurs before the ventricle contracts.

As to its being caused by contraction of the heart muscle. In this case the duration of ventricular systole must coincide in length with the first sound, or, in other words, the second sound and closure of the semilunar valves occur in ventricular diastole, and some time after it has begun, which is inconsistent with results obtained from simultaneous cardiograph and sphygmograph observations. In fact, this view of the causation of the first sound seems to be supported by only one experiment, viz., that of Ludwig and Dogiel, which consisted in ligaturing, in order of the flow of blood, all the vessels of the heart. The heart, however, presumably empty, continuing to contract, caused a sound. From this it was inferred that the contraction of the muscle can cause a sound.

Now, if there were nothing whatever in the heart, then all the internal surfaces would be in contact, and it is exceedingly difficult to understand how it could contract since it could not relax, the "contraction remainder" owing to atmospheric pressure being enormous.

If, however, it did contain any fluid such as a little muscle serum, it could readily cause vibration of the valves and a sound.

Now, disregarding any other evidence against this view, such as the fact that the heart muscle cannot undergo tetanus, a reference to Professor Halford's original experiment is sufficient to completely disprove the supposition that the contraction of the heart muscle is a factor in the production of the first sound.

If the heart of a living dog is exposed, artificial respiration being kept up, and a stethoscope placed on the heart, the first sound will be heard. If now the superior and inferior cavæ be clamped outside the pericardium, after a beat or two the sound ceases although contraction continues, *i.e., there is muscular contraction but no sound.* After repeating this, blindfold an observer, and let him listen to the sound, then alternately clamp and release the veins (or to use a popular term, "dodge him"), the result will be uniform. Once with Professor Halford, and once with

me, the experiment failed, but, on searching, in each case an azygos vein was found entering the right auricle behind. On clamping it the experiment again succeeded. This variety is not uncommon in Colonial dogs.

This experiment is simply conclusive, and can readily be performed by any one. In an hour the observer can be quite satisfied as to the cause of the first heart sound.

The muscoli papillares pull the valve one way, and the blood pushes it another, but as the two forces are not mathematically equal, a to-and-fro movement—a vibration in fact—is set up and causes the sound.

This agrees with cardiograph experiments, which tend to show that the first sound lasts only so long as blood is contained in the ventricle during ventricular systole.

(B.) On the Mode of Action of the Cardiac Muscles.

The following doctrines with regard to this subject are merely mentioned because they are inconsistent with the results of experiments performed in the Melbourne School:—

1. The increase in the antero-posterior diameter of the heart is apparent not real, and is due to the rotation of the heart on its long axis.
2. There is no shortening of the distance from the auriculo-ventricular line to the apex, except slightly at the conus arteriosus.
3. The whole heart is pushed down by the expansion of the pulmonary artery and aorta.
4. The upward movement of pins stuck through the chest-wall into the ventricle is due to the rotation of the heart.

If the heart be exposed in a medium-sized dog, in which the pericardium, whilst tough, is tolerably transparent,—great care being taken not to injure the pericardium—and needles be put into the apex, the middle of the ventricles, the auriculo-ventricular line, and the auricles, the needles will move up and down, and but slightly laterally.

The one at the apex moves very slightly, and that at the auriculo-ventricular groove very greatly. Here the fulcrum on which they move is the pericardium not the chest-wall, and if there were much rotation of the heart, they would show marked

lateral movement. Further, it can be seen that the rotatory movement is not very great. The auriculo-ventricular groove is covered with fat, and is thus easily seen to move vertically at each contraction. The pericardium itself moves but slightly, and seems to be of much the same bulk all through.

When the ventricles contract the auriculo-ventricular line descends, and the distended auricles occupy the upper part of the space. When they contract the auriculo-ventricular line ascends, and the ventricles occupy the greater part of the space, *i.e.*, the base and apex are the most fixed parts of the heart, and the auriculo-ventricular line the most movable.

If the abdomen be opened, and that part of the diaphragm which corresponds to the apex be watched, it will be seen to be comparatively motionless, *i.e.*, the heart as a whole is not pushed down, as was shown by the pin experiment.

If the pulmonary artery and aorta be laid bare it will often be difficult to see the expansion. If they are to push the heart down, they must have some point to act from. They are far more likely to push the areolar tissue in the mediastinum up than the heart down, if they did exercise any such force.

Lastly, paradoxical as such a statement may seem, "the apex is the point from which the longitudinal fibres of the ventricles act and pull down the auriculo-ventricular line," for the apex does not move downward, and it cannot move upward since there is nothing to take the place, and lateral movement is prevented by the pericardium.

As it is therefore fixed, it is the *point d'appui* of the longitudinal ventricular fibres, just as the base of the heart is that of the longitudinal auricular fibres, so that all the longitudinal fibres may be regarded as being inserted into the auriculo-ventricular groove.

But all these statements are true, only so long as the pericardium is intact, since it is the great regulator of the action of the muscle.

Now cut it down the middle. In a moment the apex of the heart flies forward. The auriculo-ventricular groove no longer moves very much, but the apex is dragged upward at each contraction of the ventricles. The *point d'appui* of the longi-

tudinal ventricular fibres is changed, and the action of the muscle completely altered.

It will be seen then that the auriculo-ventricular groove moves in ordinary action up and down, according as it is acted on by the ventricular or auricular longitudinal fibres, and that the apex and base of the heart are the most fixed points. It is probable that at each contraction there is slight rotation and shortening of the interventricular spiral also.

These experiments were carefully conducted with the aid of anæsthetics.

NOTES ON RAISING THE ARM. By Professor CLELAND,
F.R.S., University of Glasgow.

THE remarks made by Dr Cathcart in the last number of this *Journal*, respecting the movements of the shoulder girdle in raising the arm from the side, have interested me more particularly on account of the quotation from Quain's *Anatomy*. The doctrines quoted from the ninth edition of that work are mostly taught in the seventh edition also; and I have to acknowledge the statements there made to be a fair expression of views which I held, and accept responsibility in connection with them. They do contain an inaccuracy, the existence of which, to a limited extent, had already come under my notice in observing the movements in the living subject, but the exact nature of which I failed to define. Dr Cathcart is perfectly correct in drawing attention to rotation of the scapula always taking place in raising the arm to right angles with the trunk. The statement that "the deltoid muscle raises the arm from the side as far as the structure of the shoulder-joint permits, that is, till it is at right angles with the trunk" ("Quain," 7th ed., vol. i. p. 212) ought to have the word "trunk" replaced by "base of scapula." It would then be an accurate sentence to place at the commencement of an account of the action of the deltoid muscle. However, the correction has not been made by the editors of the eighth and ninth editions. This account of the extent of elevation allowed at the shoulder-joint is in general terms accurate, although it might have been mentioned, that with the arm supinated the humerus can be rolled on the scapula to a further elevation than when it is pronated.

Talking, however, of undetected errors made eighteen years ago, I may point out that I would not now attribute to the acromion the function of preventing further elevation at the shoulder-joint. This blunder is not improved by saying that the movements are "checked by the upper end of the bone meeting the coraco-acromial ligament" ("Quain," 9th ed., vol. i. p. 155). The limitations of movement at the shoulder-joint are due to the structure of the joint itself, the glenoid ligament

fitting in different positions of the elevated arm into the anatomical neck of the humerus. Indeed, in connection with this there is a very beautiful arrangement which comes into play in two frequently employed positions of stability of the shoulder. There are three positions of the shoulder specially stable or fitted to resist pressure. One is when with the arm directed downwards pressure is exerted upwards, as in supporting the weight of the body on the arms or raising it up. Then the humerus is pressed on the acromio-coracoid arch, and the bursa beneath that arch has an important part to play; a very different state of matters from what is found in mammals with the clavicles absent or defective, in which the weight of the body slung between the serrati magni muscles is conducted through the heads of the scapulæ to the humeri. But there are two other positions ordinarily used in pushing. One is produced, in the detached limb, by pulling the long head of the biceps muscle while the humerus is held firm. The movement of the scapula thus produced is arrested by the upper end of the glenoid head, where the tendon is attached, being impacted in the beginning of the bicipital groove between the two tuberosities of the humerus. If now the short head of the biceps muscle be pulled, while the long head is still held tight, the glenoid surface will be so turned that the slight depression always present near the upper end of its anterior edge will be fitted with the utmost nicety to the convex upper margin of the small tuberosity of the humerus. It is superfluous to point out that these two positions of the joint are precisely those into which respectively it is thrown in continued pushing with one arm and with both.

With the assistance of Dr J. Y. Mackay and Dr R. B. Young, I have sought to arrive at a more explicit knowledge of the movements of bones and muscles actually taking place in the living body on elevating the arm. We satisfied ourselves that in some instances the outward rotation of the scapula begins coincidently with the elevation of the arm, but that this is not always the case. In one instance we noted an actual slight inward movement of the lower angle of the scapula before each elevation, the lower edge of the rhomboideus major being felt distinctly as it produced this effect. We notice that there is movement of the clavicle from the very commencement of elevation

of the arm, but not elevation of its acromial extremity. The movement is one of rotation partly, the anterior edge rotating upwards, as felt on the prominent sternal half of the bone. This results from the coraco-acromial ligaments binding down the clavicle more effectually behind than in front, and the coracoid process being displaced downwards and outwards by the rotation of the scapula. But the acromial end of the clavicle is depressed, sometimes quite distinctly, and even in extreme raising of the arm fails to become markedly, if at all, elevated. This, perhaps, is most strikingly brought out by the power of shrugging the shoulders remaining even when the arm is raised above the head. This behaviour of the clavicle is a highly important element to be considered in arriving at a just estimate of the nature of the movement by which the arm is raised.

Every part of the deltoid and trapezius swells out in the commencement of elevation of the arm. The posterior fibres of the deltoid are, however, not effective in producing the elevation, as manifestly their points of attachment retreat from one another; and the attachments of the anterior fibres retreat from one another in the commencement of the movement, if the body be bent forwards.

In a former number of this *Journal* (May 1871) I demonstrated that, in all circumstances, the scapulo-clavicular arch is hung from the trapezius muscle, and prevented from falling downwards and forwards into a position impossible of attainment without paralysis or loss of that muscle. It is obvious that the contraction of the deltoid and supra-spinatus is a downward pull upon the arch, and it is resisted by contraction of the trapezius. The slight variations in behaviour of the outer end of the clavicle in different persons, when the arm is raised, depends on variation in the relative proportion of the antagonistic forces, the trapezius drawing the clavicle backwards and upwards over the convexity of the thorax, and the weight of the limb, plus the contraction of the deltoid and supra-spinatus, pulling it down.

The whole trapezius has a backward pull on the clavicle and scapula, and rests them and the weight supported by them on the thoracic wall; and the more the weight is so rested, the less falls to be borne by muscular fibres.

No confusion must be allowed between the observation, on the one hand, of the possible movements of joints and the relative distances of the attachments of their muscles in the different positions of the joints, and, on the other hand, of the actual mode in which these factors are brought into play in complex movements in the living body. The latter is to be studied on the living body; but the former cannot be studied except on the dead body. It is, for example, an anatomical point beyond all question that the supra-spinatus and the main bulk of the deltoid muscles have their attachments approximated by abduction of the humerus effected at the shoulder-joint; and it would be absurd to say of such an observation on the dead body that it "can only afford us the means of modifying or corroborating, not of displacing or overthrowing, the views we have obtained from examining healthy living individuals." This I say, not because I suppose that Dr Cathcart doubts it, but because the words which he has used do not sufficiently define the provinces of observation on the living subject and on the dead.

OSTEOLOGY OF *CERYLE ALCYON*. By R. W. SHUFELDT,
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parata, Florence, Italy; Membr. American Ornithologists'
Union, &c.* (PLATE XIV.)

REPRESENTATIVES of the family *Alcedinidæ* are found pretty generally, though rather unequally, distributed over the continents of the globe. The Australian fauna claims the greatest number of genera and species; to it, however, the genus *Ceryle* is at present still unknown. On the other hand, of the one hundred and twenty or more species recognised as constituting the family, this genus alone, including some half a dozen species, occurs on the American continent. Of these species but two have a place in the ovifauna of the United States, one of which being the subject of this paper, a bird that ranges over nearly all parts of North America during the milder months; the other is the handsome green Cabains' kingfisher, which occurs occasionally in the valley of the Rio Grande, Texas, as a straggler.

Viewed as a whole, the kingfishers form a very curious group of birds; many of its members when compared with each other exhibiting, both in structure and habits, much that is different. As a rule they are birds with rather thick-set robust bodies, short legs, large heads, elegantly crested in some species, straight powerful bills, which are long and sharp-pointed, and these may be of a brilliant coral red colour—as in some of the African and East Indian forms. They make the same impression upon one's mind that the toucans do—that of being top-heavy, appearing as if it might require an effort on their part to keep their balance.

Several of the larger forms known to us are very plainly coloured—possessing only the blacks and whites or the more sombre tints of brown in their plumage. This is not the case, however, with the majority, for many of the smaller species are adorned with the most gorgeous of metallic tints—the blues and greens being the predominant shades.

The toes of their feeble non-ambulatorial feet are arranged upon nearly all the plans as they exist in these members among birds.

In *Ceryle alcyon* the foot is rendered still weaker than it is in many of its relations by nearly complete syndactylism—the middle and outer digits being encased almost to their extremities in a common podothecal sheath.

Dacelo gigas has its toes arranged upon the more universal type—that of three in front and one behind; while the tri-dactylous kingfisher of the East Indies has but two in front and one behind. Still others possess zygodactylous feet, agreeing in this respect with the *Bucerotidæ*, a group of birds, in the opinion of many ornithologists, closely akin to the kingfishers.

The typical species of the *Alcedinidæ* resort to the water-courses in the countries where they are found, and live upon small fish, which they secure by plunging into the streams or ponds after them. When successful, the prey is borne in their beaks to some resting place, usually one from which many of their sallies are made, to be devoured. Others live upon reptiles and small mammals, which they capture by pouncing down upon them, much in the same manner as those just alluded to do upon the fish in the streams—the first being really more deserving of the name of “kingfisher.”

Finally, we have those forms which are intimately connected with the *Galbulidæ*, living upon insects, which they commonly take upon the wings.

Nearly all kingfishers are noisy, restless birds; none of them sing; not one of the group as far as I know ever giving vent to anything that might be compared to a song.

Their notes range all the way from the discordant racket, which our present species is so fond of indulging in—to the hyæna-like cry of *Dacelo gigas* as it breaks the stillness of an Australian forest.

Still, I doubt very much that we could find in all England a young naturalist who could suppress his interest and enthusiasm the moment that the favourite little kingfisher of the streams of his land became the topic of conversation; much less would the older devotees of the science, who perchance have adopted other countries for their homes, part with their recollections of the azure-

tinted little sprite that haunted the river banks, where their days were spent in boyhood, during many a fishing and collecting excursion. It is just so with our New England naturalists; our memory-picture of the great broad stream at home, with its noisy mill and its drooping willows, would be incomplete without its kingfisher, and the rattle of his note has made an impression upon our ear never to be forgotten. We must believe that the thoughts of the veteran Wallace reflected homewards to the sunny banks of the Thames, when, far away in Amboyna, he first collected the racquet-tailed kingfisher. In his charming book, *The Malay Archipelago*, which I have twice read with pleasure, he tells us, relating the instance, that "these birds differ from all other kingfishers (which have usually short tails) by having the two middle tail-feathers immensely lengthened, and very narrowly webbed, but terminated by a spoon-shaped enlargement, as in the motmots and some of the humming-birds. They belong to that division of the family termed king-hunters, living chiefly on insects and small land-molluscs, which they dart down upon and pick up from the ground, just as a kingfisher picks a fish out of the water. They are confined to a very limited area, comprising the Moluccas, New Guinea, and Northern Australia. About ten species of these birds are now known, all much resembling each other, but yet sufficiently distinguishable in every locality. The Amboynese species, of which a very accurate representation is here given, is one of the largest and handsomest. It is full seventeen inches long to the tips of the tail-feathers; the bill is coral red, the under surface pure white, the back and wings deep purple, while the shoulders, head, and nape, and some spots on the upper part of the back and wings, are pure azure blue. The tail is white, with the feathers narrowly blue-edged, but the narrow part of the long feathers is rich blue. This was an entirely new species, and has been well named after an ocean goddess by Mr R. G. Gray."

From all that is known of the internal and external structure of the *Alcedinidæ*, authors are pretty well agreed upon the taxonomic position the family holds with respect to other groups of birds.

Systematic ornithologists still adhere to that "polymorphic group" known as picarian birds,—the order *Picariæ*. This

order—a very unnatural one, and the necessity for its existence only going to prove our lack of knowledge of the structure of the majority of the forms that have been huddled together in it—is usually considered as being divisible into three sub-orders.

These sub-orders are (1) the Cypseli, including the three families *Cypselidæ*, *Caprimulgidæ*, and *Trochilidæ*; the (2) Cuculi, which include some sixteen or seventeen families, our *Alcedinidæ* being one of them, and the most important of the others being the *Cuculidæ*, the *Bucerotidæ*, the *Galbulidæ*, the *Meropidæ*, and the *Trogonidæ*. The third sub-order is the *Pici*, into which fall the woodpeckers and wrynecks, and the family *Picumnidæ*.

This arrangement is seen to be somewhat different in Huxley's classification, based upon the structure of the palatal bones, and now familiar to all of us. Here, this author says of the *Desmognathæ*, his third sub-order of birds, that "not fewer than seven groups of families appear to me to be clearly distinguishable in this sub-order—viz., the *Chenomorphæ*, the *Amphimorphæ*, the *Pelargomorphæ*, the *Dysporomorphæ*, the *Aetomorphæ*, the *Psittacomorphæ*, and the *Coccygomorphæ*. In addition to these undoubted *Desmognathæ*, I shall at the end of this series consider the woodpeckers under the name of *Celeomorphæ*."¹

It is only those forms which this able taxonomist includes in his *Coccygomorphæ* that interest us at present. *This group is characterised in the following manner:—*

"7. COCCYGOMORPHÆ.

"The rostrum presents very various forms, and may be movably articulated with the skull. Basipterygoid processes are present only in one genus (*Trogon*).

"The maxillo-palatines are usually more or less spongy. The palatines are not developed into vertical plates, but are, as usual, horizontally flattened.

"The distal end of the quadrate bone has the ordinary form.

"The sternum usually presents two notches on each side, and has no bifurcated manubrial process (ex. *Merops*).

¹ "On the Classification of Birds," &c., *Proc. Zool. Soc.*, April 11, 1867, p. 460.

"The clavicles are convex forwards, and without any process developed backwards from the summit of their symphysis.

"The tarso-metatarsus is never remarkably elongated.

"It does not appear that anything can be predicated in common of the pterylosis or of the characters of the oil-gland in this group.

"The larynx has not more than one, or at most two, pair of intrinsic muscles.

"The *Coccygomorphæ* are readily divisible into four groups by the characters of their feet, as follows:—

"*A. The first toe turned forwards, as well as the others.*

Coliidaë.

"*B. The fourth toe temporarily, or permanently, turned backwards, as well as the first.*

Musophagidaë.

Rhamphastidaë.

Cuculidaë.

Capitonidaë.

Bucconidaë.

Galbulidaë.

"*C. The second, third, and fourth toes turned forwards; the first backwards.*

Alcedinidaë.

Meropidaë.

Bucerotidaë.

Momotidaë.

Upupidaë.

Coracidaë.

"*D. The first and second toes permanently turned backwards; the third and fourth forwards.*

Trogonidaë.

"This group, as I have already intimated, appears to occupy the centre of the Desmognathous division—the *Musophagidaë* approaching the Aetomorphæ, the *Trogonidaë* the Cypselomorphæ, and the *Alcedinidaë* the Pelargomorphæ."¹

In two genera of kingfishers—*Alcyone* and *Ceyx*—but three toes occur on each foot, abortion of the second digit having taken place in the feet of the species comprising them.

As little is known of the anatomical structure of the group,

¹ "On the Classification of Birds," &c., *Proc. Zool. Soc.*, April 11, 1867, p. 466-67.

I was encouraged in the hope, that adding the description of the skeleton of so important a representative as the Belted Kingfisher to the literature of the subject, would prove of interest and perhaps value. Upon the drawings in Plate XIV. I have bestowed great pains, and they may be at least relied upon as accurate. Mr Alfred Newton tells us with great truth that "it is to be regretted that hitherto no light has been shed by palæontologists on this interesting subject, for the only fossil referred to the neighbourhood of the family is the *Halcyorius toliapicus* of Professor Owen (*Br. Foss. Mamm. and Birds*, p. 554), from the Eocene of Sheppy—the very specimen said to have been previously placed by König (*Icon. foss. Sectiles*, fig. 153) in the genus *Larus*." ¹

Touching then, as I have in the foregoing paragraphs, in as brief and comprehensive a manner as possible, and yet as fully as such an essay as this demands, upon the general characteristics of kingfishers,—their distribution, their mode of life, and the views of the leading authorities upon their toxonomy, we will now proceed to a study of the skeleton, and commence this with an examination.

Of the Skull.—Not having a young kingfisher at hand, it will be impossible to define with absolute certainty the sutures among the various bones of the skull of this bird. In a great many cases they have been completely obliterated; but as it is my intention to confine my observations in this paper to the adult skeleton, rather than to its development, this is not of so much consequence. We have every reason to believe, however, that the skull has been formed by the union of the usual bones found in ordinary birds' heads, though one has resulted, which in many respects is very different from the more common pattern, and presenting points of interest peculiarly its own. By consulting the three first figures of Plate XIV., it will be seen that the upper mandible has the form of a three-sided pyramid, with a broad base and sharp-pointed apex. The base seems to rest upon the remainder of the skull, and the bones of the same appear to stop abruptly as they reach it. In its plane above we see a strongly-marked fronto-maxillary suture (fig. 2); while nearly in a vertical line beneath we notice the apparent sudden

¹ *Ency. Brit.*, 9th ed., p. 82, art. "Kingfisher."

termination of the palatines and maxillaries (Plate XIV. fig. 3). The actual base of this pyramid is formed by the great spongy maxillo-palatines, which here bound the rhinal chamber anteriorly, being pierced above only by the cylindrical nasal tubes which lead to the external nostrils. These latter are elliptical in outline, with their major axes parallel with the long axis of the pyramid, being separated from each other by a solid bony septum narium, and situated, as we see them in fig. 2 of Plate XIV., on the flat sides of the mandible.

In *Alcedo ispida* the septum narium is pierced by an oval foramen, at about its centre. Just to the rear of their posterior border in *Ceryle*, on either side, there is to be found a small circular foramen leading into the nasal passages already mentioned, that course the maxillo-palatines (fig. 2, *nf*). These foramina are absent in *Alcedo*.

The culmen, which forms one angle of this mandibular pyramid, is rounded; the tomium, or those edges which correspond to them in the skull, are quite sharp, and slightly raised above the remaining side, which they bound. This side, constituting as it does the roof of the anterior portion of the mouth, is an unbroken, smooth, horizontal surface; its median and longitudinal line being marked by a distinct groove, which becomes broader behind, to merge into the maxillo-palatines, between the latter bones (Plate XIV. fig. 3).

We find this mandible in *Ceryle*, although having a very solid appearance from being closed in on all sides as it is, to be extremely light, having internally very much the same structure as in the hornbills, only rather coarser.

There is one other feature we notice on the superior aspect of the mandible in *Alcedo* that is absent in *Ceryle*; this is a pretty well marked groove, leading on either side from the anterior margin of the nostril back to the maxillary. It is shown in the drawing of this view of the skull here presented, from a specimen kindly lent me by Mr F. A. Lucas of the United States National Museum (*k*, fig. 1, *b*). Regarding the skull of our kingfisher from above, we find the superior margins of the orbits sharp and regular, and separated from each other by the smooth, rather broad surface of the frontal region. This is slightly indented longitudinally by a shallow median groove that tra-

verses the cranium from the fronto-maxillary line, through the parietal portion. Here the surface is raised, on either side, into smooth rounded domes, that are bounded behind by the prominent and projecting temporal fossæ. These latter are divided behind by a sharp median ridge (Plate XIV. fig. 2). All these features, though present in *Alcedo*, are far less noticeable, while the median ridge tends to merge into the surrounding surfaces. This is completely effected in the skull of *Geococcyx*, where the temporal fossæ are well separated, and the median ridge has become a broad surface, indistinguishable from the general

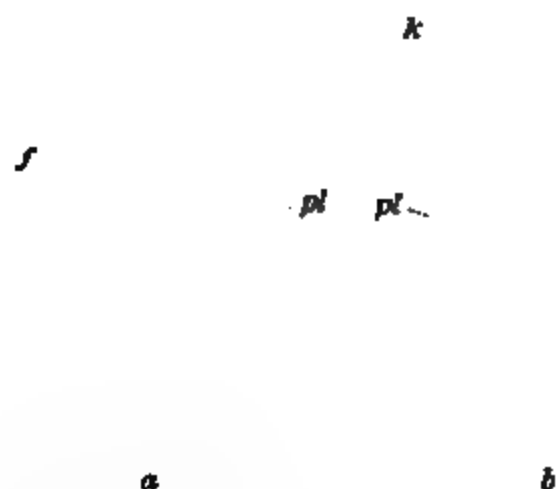


FIG. 1.—Superior (b) and inferior (a) views of the skull of *Alcedo isipida*. *l*, lacrimal; *pl*, palatine; *k*, inter-naso-maxillary groove on the mandible; and *f*, the maxillary. Life size from nature.

superficies of the cranial vault. Holding a mid position between these two conditions, we find an example in the skull of *Coccyzus americanus*, where the fossæ approach each other again. If we suppose a perpendicular to be let fall through the skull to a point just a little beyond the condyle, it is observed that the plane of the occipital surface makes an angle with this line of about 15°. It is gently undulating in character, the foramen magnum being found in its lower third. The usual nervous and

vascular foramina are seen on either side of this, and rather deep sinus canals above. Its superior margin in *Ceryle* is very sharp, while in *Alcedo* and *Geococcyx*, where this surface has the same general character, this boundary is more rounded.

Viewing the skull laterally (Plate XIV. fig. 1), the unusually deep temporal fossa is again brought to our notice, occupying much of the space behind, terminating only at the superior margin of the ear cavity, and allowing but just enough surface for the lodgment of the head of the quadrate. It has above it a flattened squamosal process, which is separated by a shallow concavity, still more anteriorly, from a feebly pronounced post-frontal projection. The ali-sphenoidal wall bulges forward in the form of an elevated dome, a feature characteristic also of *Alcedo*. Above, the thin and horizontal frontal affords the orbit an ample roof, this bone being carried forward to join with the extension surface of the superior portion of the large lacrymal.

If we look at a lacrymal from above (Plate XIV. fig. 2, *l*), it presents an oblong surface with slightly rounded angles. Its inner margin articulates closely with the nasal anteriorly and the frontal behind, about one-third being devoted to the former and the remaining two-thirds to the latter bone. There is thrown down from beneath this superior oblong plate of the lacrymal, the connection being a somewhat constricted neck, another plate, which forms the greater part of the anterior wall of the orbit. This plate has a smooth surface with a light, spongy interior; its shape is square, with rounded angles. Its outer portion below rests upon the horizontally expanded maxillary, while its inner and upper angle has wedged into it a small oblong process that is developed from the ethmoid. The two close in above a large elliptical foramen, through which, in life, the nasal nerve and vessels pass. This inferior plate of the lacrymal is nearly double the size of the superior, and is placed at right angles to it.

In *Alcedo ispida*, the arrangement for the lacrymal which we have here given is substantially the same. It differs principally in being thicker from before backwards, and the process from the ethmoid, which in this kingfisher is triangular, meets it about the middle of the inner border rather than the superior and inner angle, as it does in *Ceryle*. In *Geococcyx*, the superior plate has

moved down on the margin of the orbit nearer the maxillary, articulating almost exclusively with the nasal. This change nearly does away with any distinction between an inferior and superior plate, the two having run together in nearly the same plane.

The ethmoid here develops a very large wing-like plate, and the lacrymal is so twisted to pass down in front of it, the former really forming the anterior wall of the orbit. In *Coccyzus americanus*, the ethmoidal wing is very extensive, and forms the entire inter-orbito-rhinal partition, while the lacrymal barely articulates with it, it being a light little bone, having very much the form we find in *Oryzopsis*.

One large vacuity is found in the interorbital septum in *Ceryle alcyon*, as shown in Plate XIV. fig. 1. This has the appearance of being divided in two by a very narrow isthmus of bone above in *Alcedo*, but we find this deception due to the large foramina for the exit of the nasal nerves from the brain case in this bird, these openings being exceedingly small in *Ceryle*.

The quadrate presents little or nothing that is peculiar. Its orbital process is sharp and spine-like, projecting into the orbital space, though overshadowed by the bulging wall of the alisphenoid above. This process of the quadrate is remarkably stumpy and short in *Alcedo*, while it is broad and flat in *Geococcyx* and *Coccyzus*, where it almost rests against the posterior wall of the orbit.

Upon the inferior view of the skull of *Ceryle*, we observe the anterior extremities of the palatines to be broad, horizontally flattened and thin plates. They are separated from each other by an interval of about 2 mm., and merge beyond into the bony roof of the mouth already alluded to. The interval between their anterior ends is continued backwards to a point well within the articulation of the heads that articulate with the pterygoids. Near their inner margins, posteriorly, quite a large foramen exists in each, though I cannot say it is a constant character, opposite the anterior projection of the ethmoid. Each palatine throws up a triangular plate of bone to project freely into the rhinal space. The outer and posterior angles of these bones are truncate, the right hand in my specimen being notched (Plate XIV. fig. 3).

Referring to the cut of the inferior view of the skull of

Alcedo accompanying this paper, we observe that these angles are produced backwards into long needle-like processes.

This is characteristic also of *Dacelo gigantea*,¹ while "in *Merops* the long and slender palatines are devoid of any postero-external elongations."²

In my specimens of *Coccyzus americanus* there are no such processes present, but the angles are distinctly defined, differing in this respect from *Cuculus canorus*, where "the palatines are rounded off postero-externally" (Huxley). This is the case also in the skulls I have at hand of *Geococcyx*, but Professor Huxley found them to be distinctly indicated in the specimens he examined of this bird, so here this character may vary perhaps with the age of the individual.

I find no vomer in *Ceryle alcyon*, and in this it agrees with others of the group, for we know "in kingfishers and hoopoes there is no vomer."³

In our kingfisher the pterygoids are very long and straight, their distal extremities having on their outer sides little horizontally flattened and projecting triangular processes, an absent feature in *Alcedo*, *Geococcyx*, and *Coccyzus*. None of the forms just mentioned possess basi-ptyergoid processes, and the pterygoids in the ground cuckoo are very short in comparison with the great length of the skull, being somewhat shorter than they are in *Alcedo*.

In *Ceryle* the maxillaries are broad, horizontally expanded plates (Plate XIV. fig. 3), passing into the extensively developed maxillo-palatine masses, anteriorly, which nearly fill up the forward part of the rhinal chamber. In *Alcedo* this expansion is not particularly noticeable, while in other respects the arrangement of these parts is the same.

These two kingfishers differ from each other in the manner the quadrato-jugal bar articulates with the quadrate. In *Ceryle* it is received into an articulating socket on the outer side of this bone, while in *Alcedo* it meets it much more anteriorly, though somewhat laterally.

¹ Huxley, "Classification of Birds," &c., *Proc. Zool. Soc.*, April 11, 1867, p. 447, fig. 29.

² Huxley, "Classification of Birds," &c., *Proc. Zool. Soc.*, April 11, 1867, p. 448.

³ Parker, *Morphology of the Skull*, p. 264.

The form of the lower mandible is well shown in Plate XIV. figs. 1 and 3. It does not essentially differ in *Alcedo ispida*. Both of these birds have the ramal vacuity spanned across with a thin plate of bone, which may be pierced by a minute foramen. Among the cuckoos this bone is very much more like the general form as we find it in the Passerine types.

In *Coccyzus* a large ramal vacuity exists, and the internal angular processes are long and pointed, curving upwards, while rudimentary posterior angular processes here commence to make their appearance.

Nothing worthy of particular note rewards our examination of the internal aspect of the brain case. The usual sclerotal plates are present in the eyes, and proportionate in size with the other parts. Arrangement of the ear-cell is very simple; the delicate bony tie beams found in its interior in so many birds is here replaced by solid bone, pierced only by the necessary openings.

The hyoid apparatus (fig. 7) departs very markedly from ordinary birds. This is seen principally in the broad first basi-branchial (*bh*), with its slender, connate second basi-branchial (*bbh*) reduced in this bird to a mere spine of no great length. The epi-branchials are very much shortened, and extremely delicate in structure, being tipped behind as usual with cartilage. Behind the glossohyal (*gh*) is broad and quadrilateral in outline, the cerato-hyals being scarcely discernible at its posterior and outer angles.

Of the Axial Skeleton.—The vertebræ of *Ceryle*, when compared with many other birds of about the same size, are large in comparison, with prominent processes. We find nothing to particularly distinguish the atlas. The plate closing in the neural canal of this segment above is oblong in outline, with a minute spine at each outer and posterior angle. The body is thick from before backwards, so the shallow cup for the occipital condyle is never perforate, as it is in many birds. A large neural spine is found on the axis, and the diapophyses are elevated. Situated somewhat posteriorly, a neural spine, smaller than that of the axis, is found on the third vertebra, and this process diminishes in size as we proceed backwards, to disappear entirely on the ninth vertebra. The twelfth has a small one again, becomes larger still in the thirteenth, and in the next

of the series appears very much like the elevated quadrate plates as seen in the dorsals. In the third vertebra the foramen found in the plate between the pre- and post-zygapophyses, as a common avian characteristic, is here scarcely perceptible. But in this vertebra two other features arise—the cervical extremity of the vertebral canal, with minute parapophyses projecting from it on either side, and the appearance of an hypapophysis beneath. The vertebral canal persists through the cervical chain to include the twelfth vertebra; in the thirteenth it is closed in by a very delicate little rib, consisting of but scarcely anything more than head, neck, and tubercle. In the fourth vertebra the hypapophysis is but feebly developed, while the parapophyses are much stronger; these latter disappear in the twelfth vertebra. The carotid canal marks the inferior surfaces of the centre of the fifth to the ninth vertebræ inclusive; while in the tenth, eleventh, and twelfth a median single plate reproduces the hypapophysis once more. This process is three-pronged in the thirteenth, bifurcate, with nearly horizontal limbs, in the fourteenth, which decrease in size in the next, still to persist in the first and second dorsal, to become a single plate again in the third dorsal, and disappear altogether or be quite rudimentary in the fourth or last dorsal vertebra. The fourteenth cervical bears a pair of good-sized free ribs, but they are without unciform processes. These appendages appear, however, on the next pair, which are also free, being suspended from the fifteenth or last cervical vertebra. So there are three ultimate segments in this division of the column that support each a pair of free ribs. The four dorsal vertebræ, with their ribs connecting with the sternum, have nothing very peculiar to mark them. They freely articulate with each other, and develop stumpy metapophyses on their transverse processes. The unciform projections are not ankylosed with the ribs. Two pairs of ribs are suspended from beneath the ilia, belonging to the antecedent vertebræ of the so-called “sacrum.” The first pair have small unciform processes, their hæmapophyses articulating with these bones on the last dorsals in the usual manner; the last pair, which are very delicate in structure, vary exceedingly in length, and terminate in free extremities.

For convenience sake, we will describe the compound bone

composed of the next twelve anchylosed vertebræ, with the ossa innominata, as the pelvis (Plate XIV. fig 8). In our kingfisher it is quite narrow anteriorly, with shallow and open ilio-neural canals, divided by the common sub-compressed neural spine. This soon merges into the broad and smooth surface that forms the greater part of the superior aspect of this bone, being quite devoid of any particular points for examination beyond a few foramina as we near the caudal end.

We note on the outer iliac margins, on either side, a sharp triangular process, directed backwards, that is quite characteristic of *Ceryle*. The caudal vertebræ are seven in number, including the pygostyle. They have wide extending transverse processes (Plate XIV. fig. 8), the last three and the coccygeal vomer developing bifurcate hypapophyses below.

The *sternum* of *Ceryle alcyon* is rather a curiously-formed bone, and quite differently shaped from the sterna of ordinary birds (Plate XIV. figs. 10 and 11). At its hinder extremity it is four-notched, with the outer pair of xiphoidal processes dilated at their extremities. This dilatation is observable, though not to such a marked degree in the inner pair. Four facets for the hæmapophyses of the dorsal ribs are found on the superior aspect of each costal border, and beyond the anterior ones prominent costal processes arise. The keel protrudes far beyond the body of the bone, its upper and anterior angle being rounded off, the opposite condition being the case in the inferior one. The grooves for the coracoids do not meet in the median plane by a millimetre or two, and a deep pit is found on the superior surface of the protruding keel, mesiad, between the inner and lower angles of these bones. Complete abortion of the manubrium has taken place; not a vestige of such a process can be seen. Indeed, the coracoidal facets are the most projecting parts of the sternal body. A single circular pneumatic foramen, which is constant, is found on the superior aspect of the body in the middle line, where it terminates anteriorly.

With respect to the bones of the *shoulder girdle* (Plate XIV. fig. 9) we find a scapula to be quite broad, of nearly uniform width throughout, being obliquely truncate at its posterior end. The coracoid is considerably dilated at its sternal end, with raised facet on its posterior aspect for the sternal articulation. The

clavicular limbs are very broad above, and much compressed from side to side, being reduced to thin blade-like bones; their scapular heads reach far backwards, and afford quite an articular surface for these bones. No hypocleidium exists at their mesial union, but the lower part of this U-shaped arch is curved upwards and backwards. In the articulated skeleton (Army Medical Museum, Washington, Section Comparative Anatomy, No. 155) it rests against the anterior border of the sternal keel at the junction of the middle and lower third.

Of the Appendicular Skeleton.—In the pectoral limb the humerus is the only bone possessed of pneumaticity. Proportionately it is very long—being but $\frac{2}{3}$ ths shorter than the bones of the antibrachium. Its radial crest is but moderately developed, but in other respects this bone presents the usual characters found among birds generally. The osseous tubercles for the quill-butts of the secondaries, found in many of the class along the shaft of the ulna, are here absent or very faintly perceptible in some specimens. Both bones of the antibrachium in the well-developed limit of this kingfisher are as we usually find them in ordinary birds. The two carpal segments are well apart from each other, thus affording quite an extensive share of the head of the metacarpus for articular surface for radius and ulna.

One phalanx is allotted to pollex digit, two to index, and one to medius, claws and spurs being absent in the manus of *Ceryle*.

The pelvic limb is entirely non-pneumatic, and is interesting principally in the evident feebleness of the foot (Plate XIV. figs. 5 and 6). In the *femur* the shaft is straight and cylindrical, being unmarked by ridges or lines for muscular attachment. An ordinary avian *patella* is present. On the proximal and anterior aspect of the tibia the pro- and ecto-cnemial ridges are but feebly produced, and the leg-bones lend their share to the general weakness of this extremity, or really, more correctly speaking, when referring to this part of it, its small size in comparison with the rest of the skeleton. The *fibula* has but a slender spine of bone below the fibular ridge of its companion with which it articulates, and in some specimens I find even this missing. When this latter condition exists, *Ceryle* has as short a fibula as any bird with which I am at present acquainted.

The *tarso-metatarsus* is less than a third as long as the shaft of the tibia (Plate XIV. fig. 6, *mt'*.); the free metatarsal for hallux thus being obliged to take a position in articulation very near the middle of the shaft of this bone. The "hypotarsus" is large in proportion, and exhibits but a single longitudinal groove posteriorly for the passage of the tendons. The digits of the foot possess the normal number of phalanges, as they occur in the class. They have the usual form and proportionate lengths, but careful examination of the opposed surfaces of the bones composing the outer and middle toes show the effect of their being so long strapped together in a common podathecal sheath, in the evident compression of the ridges and elevations usually found on these phalangeal bones in feet where the digits are free.

DESCRIPTION OF PLATE XIV.

Fig. 1. Right lateral view of the skull and lower mandible of *Ceryle alcyon*, life size; *l*, lacrymal; *nf*, nasal foramen; *na*, nasal septum; *q*, quadrate; *pg*, pterygoid; *pl*, palatine; *m*, maxillary.

Fig. 2. Superior view of skull of *Ceryle alcyon*, lower mandible removed, life size, letters as in figure 1.

Fig. 3. Basal view of skull of *Ceryle alcyon*, lower mandible removed, life size, letters as before, with *s*, sinus canal; *fm*, foramen magnum.

Fig. 4. Superior view of lower mandible of *Ceryle alcyon*, life size.

Fig. 5. Left pelvic limb of *Ceryle alcyon*, life size; *F*, femur; *P*, patella; *Fb*, fibula; *T*, tibia; *j*, hallucal metatarsal; *h*, phalanx of hallux; *mt*, tarso-metatarsus.

Fig. 6. The tarso-metatarsus, *mt*, in front view, life size, from same limb.

Fig. 7. The hyobranchial apparatus of *Ceryle alcyon*, viewed from above, life size; *gh*, glosso-hyal; *ch*, cerato-hyal; *bh*, first basi-branchial; *bbh*, second basi-branchial; *c.br*, cerato-branchial; *e.br*, epi-branchial.

Fig. 8. Superior view of pelvis, coccygeal vertebræ and pygostyle *in situ*, of *Ceryle alcyon*, life size.

Fig. 9. Left lateral view of shoulder girdle of *Ceryle alcyon*; bones bearing proper relation to each other, life size; *S*, scapula; *C*, coracoid; *Cl*, clavicle.

Fig. 10. Lower view of sternum of *Ceryle alcyon*, life size, and shows very well how far the keel in the curiously shaped sternum of this bird projects beyond the body of the bone.

Fig. 11. Left lateral view of sternum of *Ceryle alcyon*, life size; *o*, the usual site of the manubrium, which is absent in this bird.

NOTES ON ABNORMALITIES, WITH SPECIAL REFERENCE TO THE VERTEBRAL ARTERIES.¹ By A. M. PATERSON, M.B., C.M., M.R.C.S., *Demonstrator of Anatomy, The Owens College, Manchester.* (PLATE XV.)

I. *Right Vertebral Artery springing from the aortic arch beyond the left subclavian.* (Plate XV. figs. 1 and 2.)

The right vertebral artery arose from the posterior part of the aortic arch, at the level of the ductus arteriosus, and about three-quarters of an inch beyond the left subclavian. Lying at first on the vertebral column, the vessel passed upwards and to the right side, behind the trachea and oesophagus, and then ascended to the root of the neck behind the upper part of the right pleura. As the artery coursed over the first rib, it was closely connected anteriorly with the gangliated cord of the sympathetic, which at this spot sent large and numerous branches behind it. Passing transversely over the vessel were the superior intercostal artery, arising in this case from the first part of the subclavian, and, more superficially, the subclavian trunk itself. The vertebral artery disappeared by entering the foramen in the transverse process of the seventh cervical vertebra. Hereafter its course was regular. Before entering the vertebralarterial canal the abnormal vessel gave off no branches. The size of the artery was smaller than usual, the left vertebral being much larger.

The other branches from the aortic arch were regular.

II. *Aortic arch with three unusual primary branches: firstly, a common trunk, forming the innominate and left common carotid; secondly, the left vertebral; and thirdly, the left subclavian. Also a thyroidea ima artery springing from the innominate.* (Plate XV. fig 3.)

A short, wide trunk arose from the centre of the transverse

¹ In connection with the following remarks on the abnormalities of the large blood-vessels, I must acknowledge the great assistance I have gained from Professor Turner's valuable paper on the "Irregularities of the Large Blood-Vessels," in the *Medico-Chirurgical Review* for 1862, in addition to the authorities mentioned below.

part of the aortic arch, passed upwards, lying upon the trachea, for a distance of half an inch, and then bifurcated, forming by its division the innominate and left common carotid arteries. From the front of the innominate artery, about half an inch before its division into right subclavian and common carotid, a slender vessel (thyroidea ima) arose, which, passing upwards and towards the median line, upon the trachea, ended by anastomosing with the other vessels in the thyroid body.

The second trunk springing from the aortic arch was the left vertebral artery. It arose about half an inch beyond the first trunk, and close to the left subclavian. Passing vertically upwards in relation to the right side and posterior aspect of the left subclavian, the vertebral artery entered the foramen in the transverse process of the sixth cervical vertebra. It had no branches in the thorax, and its after course was normal.

The left subclavian artery, arising from the aortic arch close to the above, was regular in its course and relations.

Of the first of these abnormalities two examples have been recorded, the one by Hyrtl,¹ the other by Struthers.² All three cases are essentially similar. In Hyrtl's case—a new-born child—the origin of the vertebral artery was above the ductus arteriosus: the vessel descended slightly before passing upwards. Moreover, in the neck the artery entered the foramen transversarium of the sixth cervical vertebra. In the case recorded by Professor Struthers, the abnormal artery is only incidentally mentioned, but its arrangement appears to have been identical with what has been described above. The vessel entered the foramen in the transverse process of the seventh cervical vertebra.

The second case described is peculiar in having three abnormalities, each common enough separately, grouped together in one subject. The origin of the innominate and left common carotid arteries by a common trunk is said by Quain³ to be the commonest variation in the origin of the primary branches of the aortic arch. He notes it as occurring twenty-five times in 291 cases examined. It also occurs normally in rodents and

¹ Canstatt's *Jahresbericht der gesamten Medicin*, 1859, vierter Band, Specielle Nosologie, p. 26.

² "On Variations of the Ribs and Vertebrae in Man," *Journal of Anatomy*, vol. ix.

³ "On Arteries," p. 45.

carnivora. According to the same authority,¹ the origin of the left vertebral artery from the aortic arch in the manner noted above is the commonest of those variations in which the number of the primary branches from the arch is increased. In this case, of course, there is no increase in the number of primary branches owing to the blending at their origin of the innominate and left common carotid arteries. A thyroidea ima is not common, though, when it does occur, it is usual to find it, as in this case, arising from the innominate artery. More rarely it springs from other vessels. In 291 cases, Quain notes that in seven it sprang from the innominate; once only did it take origin from the common carotid of the right side, or from the aortic arch to the left of the innominate. It occurs in the elephant as a regular branch from the innominate artery.²

The point of interest in connection with the origin of the right vertebral artery from the aortic arch, beyond the left subclavian, is that it represents at its commencement the inferior portion of the embryonic right aortic arch. The right arch in mammals normally disappears, as pointed out by Rathke,³ below the origin from it of the axillary artery. The upper part, which remains, becomes the right subclavian of human anatomy, which is formed from the fourth right vascular arch and the anastomosing vessel (part of the dorsal aortic root) between the fourth and fifth.

With regard to the right vertebral artery, Rathke points out that it is formed as a sprout from this anastomosing vessel; so that developmentally it may be considered as a primary branch from the right aortic arch.

This abnormal arrangement in the origin of the right vertebral artery is explained, therefore, by supposing the lower part of the right aortic arch to remain patent and to become connected with the vertebral artery above, while the communication between the subclavian and vertebral arteries at the point where the two vessels cross becomes obliterated.

There are many cases recorded in which the right subclavian artery springs from the aortic arch beyond the left subclavian. In such cases the lower part of the right aortic arch has re-

¹ *Op. cit.*, p. 51.

² Mayer, *Nov. Act. Acad. Caes-Leo-Car.*, vol. xxii.; Watson, "Anatomy of Indian Elephant," *Journal of Anatomy*, vol. vi., 1872.

³ *Untersuchungen über die Aortenwurzeln der Saurier*, Wien, 1857.

mained pervious. It is interesting to note in what manner the right vertebral artery may arise when this arrangement holds. It always has an intimate relation to the upper part of the embryonic right aortic arch. The vessel may arise in three ways. Firstly, and most commonly, from the right common carotid; secondly, from the aortic arch to the right of the common carotid; or thirdly, from the abnormal subclavian trunk. In the first set of cases, in which the right vertebral artery springs from the common carotid of the same side, it represents the fourth right vascular arch at its commencement, the anastomosing vessel connecting it with the lower part of the arch having disappeared. The trunk between the left aortic arch and the origin of the vertebral artery, though designated common carotid, really represents the innominate trunk. This trunk in the embryo mammal is very short. To account for the second class of cases, in which the right vertebral artery arises directly from the aortic arch, we must suppose this innominate trunk, instead of developing, as is usual, to become shorter and shorter until it disappears. The right vertebral and common carotid arteries would then spring as separate primary branches from the aortic arch. The right vertebral, in these cases also, takes the course of the right aortic arch at its commencement. The third set of cases, where the abnormal subclavian trunk gives off the right vertebral, is explained by supposing the right aortic arch obliterated between the common carotid and the origin of the vertebral artery.

These irregularities in the origin of the right vertebral artery, taken together, lead to an important deduction. When the right vertebral arises abnormally (in any of the ways mentioned) there is always an evidence of the remains of the lower part of the right aortic arch. Most commonly it is the right subclavian, but in the three first-mentioned cases it is the vertebral artery, which represents the aortic root.

Before leaving the subject of the origin of the right vertebral artery, it must be noted that besides the cases mentioned above, where the subclavian artery springs from the innominate, and the right vertebral represents the lower part of the right aortic arch, there are four highly interesting cases recorded in which the vessel had a different origin:—

1. In a case recorded by Hommel,¹ and figured by Quain,² the right vertebral artery sprang from the right common carotid. This case is well known on account of the peculiar condition of the aortic arch, which was cleft in its transverse part for the passage of the trachea and œsophagus. The arch formed a complete collar round these structures. From the posterior part, and towards the right side arose the right subclavian, and to its left the right common carotid artery, which gave off the right vertebral. From the anterior part of the collar the left common carotid and subclavian arteries arose towards the left side.

2. Meckel records a case³ in which the right vertebral artery sprang from the aortic arch; between the innominate and left common carotid trunks. The left vertebral artery in this case arose from the arch also, beyond the left common carotid.

3. The two remaining cases are identical. One is recorded by Otto,⁴ the other by Tiedemann.⁵ In both there were six primary branches from the aortic arch; common carotid, vertebral, and subclavian of each side proceeding from within outwards. These two cases are explained by supposing that the innominate artery has shortened, so as to allow the subclavian and common carotid to arise separately; while the proximal part of the subclavian has undergone a similar transformation to allow the right vertebral to spring directly from the arch. In Meckel's case the innominate artery persists, and it does not seem clear, on the developmental lines laid down by Rathke, how the right vertebral artery takes origin from the arch to the left of the innominate. Further investigations are necessary to explain both this and Hommel's case. In three of these four cases it is noted that the left vertebral appeared as a primary branch from the aortic arch. The explanation of this abnormality is not so difficult, and will be referred to in connection with the second case I have described.

Variations are met with in the origin of the right vertebral artery in cases of transposition of the aortic arch. In such cases

¹ *Commercium literarium*, Hebdom, 21, Norimbergæ, 1737.

² Plate v. fig. 8.

³ "Ueber die Bildungsfehler des Herzen," in Reil's *Archiv. für die Physiologie*, Band vi. p. 571. Halle, 1805.

⁴ Frenzel's thesis; *De ramis ex arc. Aort. insol. prodeuntibus*, Wrasilaviæ, 1835.

⁵ Tiedemann, Taf. iv. fig. 5, S. iii., Hauptgruppe Abth. 3 A.g. S. 231.

it is common for the vertebral artery to spring from it, between the right subclavian and common carotid trunks.¹ Such deviations are explained on the same lines as a similar abnormality of the left vertebral artery with a normal aortic arch, and are essentially the same.

In the second case described above, the abnormal arrangement of the left vertebral artery, which is the commonest irregularity in connection with that vessel, is interesting in relation to the homologies of the vertebral arteries. The same irregularity is mentioned incidentally in other cases discussed above. According to Rathke,² the left subclavian artery in mammals is formed as a bud from the anastomosing vessel between the fourth and fifth left vascular arches, and is homologous with the axillary artery of the right side, the right subclavian artery in its development being the homologue of the fourth left (aortic) arch. This being so, the left vertebral artery, a branch of the left subclavian, in its normal condition, is developmentally in no way homologous with the vertebral artery of the right side. The abnormalities of the left vertebral artery seem to bear this out. In the most usual deviation from the normal arrangement, when the vessel arises from the aortic arch as noted above,—the deviation may be due to a tendency to symmetrical arrangement (as seen in those cases where there have been six primary branches from the aortic arch), the part of the left subclavian prior to the origin of the vertebral artery being shortened, until the two vessels arise separately from the arch. Or, as seems more likely, there is a development of a foetal vessel, springing from the anastomosing vessel between the fourth and fifth vascular arches in the left side, and truly homologous with the right vertebral artery. The normal left vertebral artery would then be regarded as an adventitious branch from the subclavian, which, arising in closer proximity to the vertebralarterial canal, and so, meeting with less resistance, consequently develops at the expense of the other, which disappears.

Besides this abnormal arrangement in the origin of the left

¹ Otto, *Seltene Beobachtungen*, Th. 2, S. 61; Watson, "On a Case of Double Aortic Arch," *Journal of Anatomy*, vol. xi.

² *Op. cit.*

vertebral artery, it should be mentioned that there is one case on record,¹ in which the vessel sprang from the aortic arch, *beyond* the left subclavian.

There are a few rare cases recorded,² in which the vertebral arteries—and in all cases but one it has been the left—have arisen by more than one root. In the cases quoted, the left vertebral artery has had two roots of origin, one springing from the aortic arch between the left common carotid and subclavian, the other from the left subclavian artery, in the position of the normal vertebral trunk.

It seems highly probable, considering these cases of double root, in connection with the other common abnormality of the left vertebral artery, that the vessel springing from the aortic arch is the homologue of the right vertebral, and that in the normal arrangement of the arteries there is analogy, but no true homology, between the two vessels.

In the case recorded,³ in which the right vertebral artery had more than one root, there were three—two from the right subclavian, and one from the inferior thyroid artery.

III. *Branch of thoracic aorta, taking the course of a vertebral artery between the ribs and transverse processes of the upper dorsal vertebræ, and ending as the profunda cervicis.* (Plate XV. fig. 4.)

This vessel arose from the back part of the aorta at the upper border of the fifth dorsal vertebra. It passed backwards to the fourth interspace, where its direction changed. It coursed directly upwards between the necks of the ribs and the transverse processes of the vertebræ, and through the third, second, and first interspaces. Then, winding backwards still with an upward direction, the vessel passed behind the first rib, and between the semispinalis colli and complexus muscles, as the profunda cervicis artery. It ended by anastomosing with the princeps cervicis of the occipital, and sent inwards branches to join the vertebral artery. As the vessel passed through the intercostal spaces it lay in front of the anterior intercostal nerves.

¹ Walter, *Mus. Anatom.*, p. 237, Berolini, 1805.

² Quain, plate xxii. figs. 7, 8, and 9; Watson, *op. cit.*

³ Quain, plate xxiv. fig. 2.

The branches were arranged in a regular system in each interspace, and greatly resembled those of the vertebral artery in the neck. *Internally* a spinal branch passed inwards along the nerve trunk to supply the cord and membranes. *Anteriorly* smaller twigs were given off, which formed an anastomosis in the bodies of the vertebræ, and supplied the longus colli muscle. *Posteriorly* a branch passed backwards with the posterior nerve trunk, to end in the muscles of the back. *Externally* a considerable branch was given off, which passed outwards for about an inch in each space, and then divided into two, one branch lying at each border of the space, and passing forwards after the manner of an intercostal artery, lying between the muscles.

In the first interspace the vessel was joined by a small superior intercostal artery, from the third part of the subclavian. This small vessel gave off in the neck, first an ascending cervical branch, and above the first rib a small branch which passed outwards parallel to the first rib, and lying on and supplying the scalene muscles.

I have not been able to find any recorded cases of this interesting abnormality. Its peculiarity consists in its likeness to a vertebral artery, in respect to both course and distribution.

IV. *Supra-scapular artery arising from the internal mammary—on both sides. Two cases.*

Both cases were identical; the vessels arose as the internal mammary artery passed behind the first rib; then crossed outwards behind the clavicle and subclavius muscle, and in front of the subclavian vein, to take their usual course to the dorsum of the scapula.

EXPLANATION OF PLATE XV.

Fig. 1. Front view of first specimen, showing the aortic arch with its primary branches, and the trachea and œsophagus behind it. The right vertebral artery is seen passing upwards from behind the trachea and œsophagus, crossed anteriorly by the right subclavian trunk. The left vertebral is shown arising from the subclavian artery of the same side.

Fig. 2. Back view of same, showing the origin of the right verte-

bral artery from the arch of the aorta, and its course behind the trachea, œsophagus, and right subclavian artery.

Fig. 3. To illustrate second specimen. Represents the transverse part of the aortic arch, with the primary branches; firstly, a common trunk for the innominate and left common caortid; secondly, left vertebral; and lastly, left subclavian artery. Arising from the front of the innominate is seen the thyroidea ima.

Fig. 4. To illustrate third specimen. Showing aortic arch and its primary trunks, cut, lying in the vertebral column. Arising from the left subclavian artery are seen the left vertebral and superior intercostal. The proximal ends of the first four ribs are shown, with the corresponding interspaces; behind the ribs, and through the spaces, passes the artery described, giving off its branches. In the fourth interspace the vessel is seen lying in front of an intercostal nerve; in the first it is shown communicating with the superior intercostal artery, and disappearing behind the first rib.

ON MULTIPLE LYMPHATIC NÆVI OF THE SKIN,
AND THEIR RELATION TO SOME KINDRED
DISEASES OF THE LYMPHATICS. By GEORGE
HOGGAN, M.B. Edin. (PLATE XVI.)

DURING the course of the last year I had an opportunity of exhibiting before the Pathological Society of London, as card specimens, a series of microscopical preparations of a newly-observed disease of the lymphatics, to which I applied the above name. I exhibited at the same time the drawings now reproduced (figs. 3, 4, and 5), and made a few remarks, which were reproduced in the medical journals at the time; but I reserved the full account of the disease for this *Journal*, where already so many of our researches on the lymphatic system have appeared.

Although lymphatic nævi have not hitherto been recognised as such, I believe the condition to be not uncommon, quite as frequent, perhaps, as venous nævi, which I, moreover, believe it often accompanies and complicates. It also forms the initial stage or predisposing pathological condition of other diseases, such as lymphatic varix of the larger vessels, and also of elephantiasis, in the production of which it may often be the most important factor. That this has not been observed before, is probably due to the fact that no proper histological (as apart from microscopical) examination has been made of the tissues in the initial stages of the diseases, for the ordinary carmine, log-wood, or other colour stainings, would fail absolutely in making the precise diseased conditions evident. Even when the walls of the lymphatics forming the close and intricate nævoid plexus have been stained, by dilute solutions of silver injected within them, it would be difficult, in sections made perpendicular to the surface of the skin, as shown in fig. 3, to recognise that the silver-marked bands represented normal sized lymphatics, and were not the clefts and fissures which have often been described in *elephantiasis arabum*. The use of a binocular microscope would, however, settle the question, by throwing the lymphatics into beautiful relief, while sections parallel to the

surface, as in fig. 4, would put the matter entirely beyond dispute.

That the condition has not been recognised clinically, is probably due to the want of colour in such nævi, as compared with venous nævi; but there can be little doubt, from the frequency with which venous nævi have been observed in elephantiasis, that the two conditions of venous and lymphatic nævi are generally co-existent, and that conditions of hypertrophy, due really to the latter form, have, through being unrecognised, been erroneously ascribed to the former, as, for example, in Mr Thomas Smith's case of nævoid elephantiasis.¹ On the other hand, when the lymphatic nævi were small, and placed so superficially in the skin, that distension by lymph, produced at will, made them appear above the general surface, like vesicular papules, such a condition would almost certainly have been described as varicose lymphatics; indeed, the present case was introduced to my notice as one of lymphatic varix, and in that opinion I fully coincided, until histological investigation of the prepared tissues showed this diagnosis to be incorrect.

This constant association of lymphatic with venous nævi, on the one hand, and of lymphatic nævi with hypertrophic conditions of the surrounding tissue, on the other, has a special interest for me, in connection with our efforts to show, in this *Journal* and elsewhere, that, physiologically and pathologically, the lymphatics closely resemble the veins, and that the lymph contained in the lymphatics is not an effete or exhausted fluid, but rather a pure reparative material, which would certainly bring about a hypertrophied condition of the gelatinous tissue wherever the excessive number of lymphatic vessels would naturally supply an abnormal quantity of pure formative lymph.

The kindred diseases of the lymphatics to which I shall specially call attention—for the sake of comparison with the case of lymphatic nævi and with each other—are three in number, each of these being different from the others, although they have certain features in common. In the order of publication they stand as follows:—

¹ *St Barth. Hosp. Rep.*, vol. v. 1869, p. 147.

1. A Case of Lymphangioma Tuberosum Multiplex, by Kaposi and Bicsiadecki.—Hebra & Kaposi's *Diseases of the Skin*, Vol. III. of New Sydenham Translation, 1874, page 387.
2. A Case of Lymphangiectodes, &c., by Drs Tilbury and Colcott Fox (communicated October 1878).—*Transactions of Pathological Society*, 1879, page 470.
3. A Case of Lymphangioma Cutis, by Dr A. Pospelow.—*Vierteljahrschrift für Dermatologie und Syphilis*, 1879, page 521.

Of these I may make the preliminary remark, that the first two closely resemble each other, although the name applied by the Drs Fox is in my opinion the correct one, while No. 3 closely resembles my case, although the author considers it an angioma similar to that described by Kaposi, which it certainly is not; in fact, he seems to have misconceived the character of the disease.

Before, however, I pass to the consideration of the diseases of the lymphatics I have enumerated, I feel it to be very desirable first to say something about the normal arrangement of the lymphatics of the skin, more especially in consequence of some retrograde and erroneous opinions thereon, which have lately been published, and which will probably obtain wide credence.

I.—THE NORMAL ANATOMY OF THE LYMPHATICS OF THE SKIN.

Previous to the researches published by Teichmann and Neumann, we knew little or nothing of the lymphatics proper of the skin. The mercurial injections of Monro, or the dissections of Mascagni, only taught us something about the efferent lymphatics lying in the hypodermis, while the mercurial injections of Breschet, still quoted in our anatomical text-books, are wholly unreliable and unworthy of citation; and it is only when the two above-named German investigators applied the method of injection of coloured fluids that we got to any degree of correctness. The drawings of injections given by Teichmann are worthy of all praise; their only fault is their very restricted

character. Those of Neumann are more extensive, and, apart from their somewhat diagrammatic character, they give a very fair conception of the anatomy of the lymphatics of the skin. The first certain steps, however, were made by Belajeff, who used injections of solutions of nitrate of silver, thus demonstrating the character of the walls of these vessels, and affording an element of certainty in recognising those vessels which no previous investigator had yet afforded. With the conclusions of the above-named three investigators, my own researches are in general agreement. Teichmann and Belajeff demonstrated that the lymphatics never come quite close to the surface of the dermis, but that the blood capillaries are superimposed upon them, and they state (what is only partially true) that the lymphatics never enter into the papillæ. Belajeff also demonstrated, in the clearest possible manner, as remarked by Charles Robin, that there was an entire absence of all plasmatic canals in connection with the lymphatics of the skin.

In the beginning of 1879 I published, jointly with my wife, an essay on the *Comparative Anatomy of the Lymphatics of the Skin*. This was, I believe, the first research made into these lymphatics by means of imbibition of solutions of salts of silver, all previous researches having been made by means of injections. Each method has its special advantages, those of imbibition being that it shows all the communicating lymphatic branches, which injection never does, as the fluid injected always seeks the most direct course towards the centre of the system; and as the valves guarding the mouths of communicating vessels prevent regurgitation of the injected fluid, we thus get the erroneous conception of the efferent lymphatics being straight unbranched channels, while in reality they form a most intricate plexus of valved vessels. Moreover, every kind of injection fails to make the exact relations of surrounding tissues to the lymphatics evident; it shows none of their cells or fibres unless stained sections have subsequently been made, and these always give an incomplete idea of relationships. Again, in very thin skin, as for example the skin of a foetal mouse, it is absolutely impossible to inject the lymphatics, and yet such specimens are of the highest importance in studying the development of the system. Indeed, all coloured injection masses ought to be rigorously excluded

when it is a question of testing what are and what are not lymphatics; a coloured mass, when seen in the tissues, is only a proof of its own existence there. Fairly injected into the blood-vessels, we accept the evidence it offers of the presence of blood-vessels without hesitation; injected into the tissues, it may either fill an artery, a vein, or a lymphatic, and as often as not it becomes simply extravasated among the tissues, and thereupon we are presented with such conditions as evidence in support of what are often most outrageous theories.

If solution of silver salts has been injected, by making the peculiar endothelium of the lymphatics evident, it rightly stamps any vessels marked by it as lymphatics, and gives the most unequivocal proof of the non-existence of such hypothetical structures as stomata, or of any specially minute channels in connection with the lymphatics. Unfortunately, imbibition can only be applied to surfaces, and it ought therefore to be combined, in *thick* structures, with injection of silver solutions. Even, however, in the human skin I have succeeded in completing researches, both in normal and pathological conditions, without using injection, by employing the histological rings already referred to in this *Journal*. On removing, by their aid, the epidermic covering, with a sharp scalpel, the silver solution sinks deep into the gelatinous matrix of the skin, and makes all the cellular structures within it very evident. In addition to the above methods, we may take advantage of natural injection of the lymphatics of the skin, as for example in cancer (fig. 1), which gives frequently most satisfactory demonstrations. Professor Sappey's method of studying the lymphatics of the skin and intestine is also extremely valuable, but it must be cautiously interpreted, otherwise one is led (as he has certainly been led) into grievous error by it. He causes a development of minute organisms within the lymphatics, so as to make these vessels evident, but unfortunately it continually does the same within the veins, and even the arteries, as I myself recognised and pointed out to him in a preparation made by him in my presence. Worst of all, the organisms also become developed within the blood capillaries, causing distension at the anastomosing points, and contraction of the lumen elsewhere, which has led the venerable professor into describing them as the

origin of the lymphatics under the denomination of lymphatic *lacunes* and *capillicules*.¹

Without going further into methods of preparation, I may give a brief review of the conclusions arrived at by myself, referring my readers who desire precise details to the original essay.² I found that in the foetus, or in very small mammals at birth, the lymphatics originally exist in one layer or on one plane in the hypodermis, and that as growth proceeds they get separated into two divisions, the superficial or collecting lymphatics, for the most part unprovided with valves, which lie close to the outer surface of the dermis, and the deep or efferent lymphatics, all well provided with valves, which carry the lymph from the collecting plexus towards the great efferent trunks beneath the skin. In no case whatever do any of the lymphatics of the skin possess muscular fibres upon their walls, these walls being formed solely by the crenated endothelium characteristic of the lymphatic system. Fig. 1 gives a correct conception of the normal distance at which the most superficial lymphatics lie from the under surface of the epidermis over by far the greater portion of the body. In that specimen of the skin from the breast of a man, there are no papillæ into which the lymphatics could possibly enter. On the palms and soles the lymphatics may appear to lie within the larger papillæ, but in all cases there is a stratum of the gelatinous matrix of the skin intervening between the lymphatic and the epidermis covering the papilla. This question, upon which there has been great discussion is really of little or no importance, the lymphatics there being only exceptional in some animals, and wholly absent in others.

In no case do the lymphatics ever come in contact with any part of the hair follicles, sebaceous or sweat glands, or hair muscles. This is a question of the greatest importance, in view of the manifold physiological functions that have hypothetically, but erroneously, been attributed to the lymphatics of the skin. The growth downward of the structures just mentioned, pushing the lymphatics before them in early life, is one of the chief factors in causing the irregular course or distribution of the superficial

¹ *Anatomie Descriptive*, third edition, vol. ii. p. 780.

² "Etude sur les Lymphatiques de la Peau," *Journal de l'Anatomie et de la Physiologie*, January 1879.

portion of the plexus ; but, under all conditions, there is a certain thickness of dermic matrix, very well marked in the skin of man, between the nearest lymphatic and the cellular structure of any of the above-mentioned organs. In the case of man, the invaginating action of the growth of the hair follicle throws the direction of the lymphatics nearest to it at right angles to the plane of the rest of the plexus, but of course parallel to its own axis. It was impossible to show this well at *h* (figs. 2 and 4), but the use of the binocular made it abundantly evident in the thick sections these figures were drawn from. In the young of the rat, or similar small mammals, this displacing action of the hair follicle is exceedingly clear. Apart, however, from the merely anatomical appearance, examples are found in comparative anatomy which put any connection between the lymphatics and the hair or sweat apparatus altogether out of the question. The skin of the hedgehog gives remarkable facility for testing this question. In the first place, the gelatinous matrix is so delicate and peculiar that, when the epidermis is shaved off the skin of the belly, a solution of silver, applied, externally passes right through the dermis, making all the structures within it, even the hypodermic efferent lymphatics, beautifully evident. Now, in this animal, the sweat glomeruli are relatively enormous in size, and lying like a great ball on the under surface of the dermis, and it is easy to trace the well-marked lymphatics, also huge in size, passing around them, but never coming into contact with any part of the gland.

Still more clearly demonstrated is the absence of the lymphatics from the hair apparatus. On the belly of the animal, the hairs and their appendages lie in closely compressed clumps, as if about to coalesce to form the spines, as they do on the upper portions of the body. In this position they appear like little oval hills, with flat tops or table-lands, composed of a number of hairs and hair appendages. Between these hills lie valleys of clear gelatinous matrix, at the bottom of which lie one or two huge lymphatics. These lymphatics never ascend or send branches upon the hillocks of hair, and consequently the hairs and their appendages lying nearest the centre of the hillock are at a considerable distance from the nearest lymphatic. In short, the lymphatics here form great meshes, and in the centre

of each mesh lies the clump of hairs. One glance, indeed, at such a preparation is worth any amount of argument, in convincing one that the appendages of the skin have neither an anatomical nor physiological connection with the lymphatics. I have been particular in insisting upon this point, because not only Professor Sappey, but also Dr Klein, the latest investigator of these lymphatics, insists upon an intimate anatomical and physiological connection, which he demonstrates by the most interesting evidence of extravasations that I have ever yet witnessed.

The relationship of the lymphatics to the fat cells in the skin is evidently only an anatomical one, as it is elsewhere, and of course in starving animals it is not even that, for in those conditions no fat cells exist, and the same may be said of the young of many animals at the period of birth. The best proof that there is no physiological, and not necessarily any anatomical connection, between fat cells and lymphatics, is found in the mesentery of the smaller mammals. In such thin membranes, immense tracts of fat cells may be seen lying at a considerable distance from any lymphatics; in many cases, indeed, far from blood-vessels. As in such membranes, as distinguished from sections of skin, all existing elements are clearly differentiated and made evident by silver solutions, it is clear that both the formation of fat and its so-called absorption in such cells must be entirely independent of the lymphatics, and the same argument applies equally to the skin. Dr Klein, however, clings firmly to the almost exploded Hunterian doctrine of absorption, and not only insists on a physiological connection between lymphatics and fat cells in the skin, but his extravasations are offered as evidence of the existence of lymph canaliculi between the individual fat cells in the skin. These pseudo-lymphatics I hold to be erroneous and misleading.

In previous papers, I have so often discussed the question of the non-continuation of the blood-vessels into the lymphatics, and the absence of all minute openings or stomata in the walls of these vessels, or any communication through them with a non-existent system of lymph radicles, that I need not again refer to the subject here. I unhesitatingly deny their existence, and it is to be noted that the only two modern investigators who hold to

their existence, Drs Sappey and Klein, conceive conditions which are absolutely incompatible with each other, so that if one is right the other must certainly be wrong. I hold them both to be wrong, the one misled by extravasations, the other misled by mistaking the blood capillaries for *lymph capillicules and lacunes*. The lymphatics of the skin are indeed an extremely simple system of drainage channels, possessing none of the important physiological functions otherwise attributed to them, and having none of the anatomical relations with other structures, which hypotheses, conceived in ignorance, have led anatomists into supposing or proving by *manufactured* appearances.

II. LYMPHATIC NÆVI OF THE SKIN.

For an opportunity of seeing and investigating the above disease, I am indebted to Dr Colcott Fox, and I am under special obligations to Mr Arbuthnot Lane, F.R.C.S., who furnished me with the necessary material for a histological examination, and with the following brief notes of the case :—

John M., aged 9 years, had, according to his mother's account, been, generally speaking, a healthy child, until, at the age of six years, he had what appeared to be an attack of erysipelalous inflammation on the foot and lower half of the right leg. After this subsided, it left the parts swollen, and a large number of spots, of a pale purplish tint and of the size of a split pea, were observed for the first time. When, during the day, he had been much upon his legs, the swollen parts became very painful in the evening. In the following year, he had a similar attack of erysipelous inflammation in the same locality, which forced him to keep his bed for a fortnight. During the last few months that he has been in London, several similar attacks have occurred, followed by pain and oedema of the leg and ankle ; but with regard to the spots, his mother thinks that they have in no way altered since they were first noticed.

When he lies in bed, the surface of the skin of the leg and foot appear very little altered, and the spots are in no way prominent either in shape or colour. When, however, he stands or moves about much, the spots become distended like papules of a vesicular character, and this condition of distension can be easily caused at any time, even when lying in bed, by encircling the leg with the hand, and drawing it downwards against the lymphatic stream. The ease with which distension of the spots with

lymph could be effected, appeared at first sight to be due to the incompleteness of the valves of the lymphatics, consequent upon their then supposed varicose and dilated condition, although, when subsequent histological investigation had shown that each spot was a lymphatic nœvus, it was evident that distension was aided by the multitude of superficial or collecting lymphatics, which were, comparatively speaking, valveless.

Before proceeding further, it will be as well to observe the difference between the prominent features in this case and those in the other cases, as far as they are given. In the case recorded by Drs T. and C. Fox, there were warty growths, from the beginning of the disease, some of them half an inch above the surface, and they even state in italics that "*the growth is not affected by pressure, as is the case with ordinary lymphatic varices.*" These essentially different conditions explain and agree with the different histological appearances. The case recorded by Dr Kaposi is similar to that of the Drs Fox, except that the lesion was not so superficial, the histological appearances showing the disease to be the same in both cases, although its site was different. Both are wholly distinct from the case I am specially considering, which has a close affinity with the case recorded by Pospelow, who was, however, evidently mistaken in his conception of it, and erroneously imagined it to be a case of lymphangioma, similar to Kaposi's.

The following was my plan of investigation:—A small portion of the skin of the leg was carefully marked off, with regard to the lymphatic stream, and excised, under chloroform and anti-septic precautions. Whenever an incision was made, a quantity of what appeared to be clear lymph escaped from the wound, which afterwards healed rapidly, under an india-rubber bandage applied directly over the whole of the leg. A small piece of the excised portion of skin was first prepared with chloride of gold, for the purpose of detecting any alteration in the condition of the ultimate nerve terminations (see fig. 5). The process employed was first to place the fragment of skin in the juice of a fresh lemon for twenty minutes, then to wash it and place it for an hour in a half per cent. solution of chloride of gold, afterwards placing it for a few days in water acidulated with acetic acid, and exposing it to a bright light till the gold was fully reduced.

For the rest of the skin, I took a one-tenth per cent. solution of nitrate of silver in distilled water, and injected this, by means of a fine hypodermic needle and syringe, into the edge of each spot, the needle being pushed into the skin immediately underneath the epidermis, so as to be in the plane of the superficial valveless lymphatics. When the solution was injected in the direction of the *open* valves, where such might exist, the distension of each spot or vesicular papule which followed, showed that the silver solution had successfully entered. The solution was subsequently washed out of the lymphatics with distilled water and with alcohol, to fix, if possible, the distended lymphatics in that form.

The various fragments thus prepared, after having been hardened in gum and alcohol, were cut into sections perpendicular to the surface, and, in addition, one of the vesicles was cut up into sections horizontal to the surface of the skin, these sections being left pretty thick, and mounted permanently in balsam, only a very slight colour staining being added, lest it might obscure the silver stained walls of the lymphatics. Fig. 4 gives a view of the lymphatics in such a section, made horizontally through the centre of the nævoid spot. The section immediately superficial to it contained all the lymphatics corresponding to the normal superficial plexus of collecting vessels, while underneath it were other two sections, containing each of them quite as many lymphatics as are represented in the figure. Moreover, fig. 4 is drawn from the very edge of the nævus, where the vessels were very much larger than in the centre, at which place, indeed, they were so closely packed that it was almost impossible to draw them, and they could only be differentiated from each other, and their separate courses traced, by using the binocular microscope. When this was used, it was seen that, with very few exceptions, the lymphatics ran horizontally, and that they formed no distinct layers, a very slight obliquity being sufficient to enable any part of a vessel to pass into the vessels on a higher or on a lower plane. The only exception to such horizontal vessels was where hair follicles and sweat glands existed, in which case the lymphatics often ran parallel to the follicles, and consequently perpendicularly to the surface of the skin. An attempt is made to show this at the side of the three hair follicles, *hh*,

in *h*, fig. 4, where the lymphatics have been cut transversely, but it is almost impossible to give the same effect in a drawing as is seen by the use of the binocular vision.

The oblique direction in which the hair follicles lie to the plane of the drawing, makes the lymphatics appear as if they touched the hair follicle, when, as a matter of fact, they lay quite as far from it as they normally do from the lower surface of the epidermis. Their position in the present disease, where such an immense multiplication of lymphatic vessels existed at one spot, teaches a valuable lesson. It is clear, from the manner in which the silver injection was made under pressure, that if any lymphatics had existed in direct connection with the hair follicles, they would have been shown by the silver, as the whole of the lymphatics in the vicinity were shown, but even here, where innumerable lymphatics were developing where normally they had no right to develop, they never approached, at the very least, within a distance equal to their own diameter of the basement membrane of the hair follicle. In such horizontal sections of the lymphatic nævus as that which is represented, only in small part, in fig. 4, one gets the absolute certainty that one has not to deal with either varicose lymphatics, or clefts or gaps in the tissue, but with a dense plexus of normal sized, normal walled lymphatics, the cells of the walls being well shown by the silver lines. Such sections, however, only give one a conception of the superficial area, or a small part of the same, occupied by the nævus, and to observe its thickness one must have perpendicular sections also through it. This lateral view is represented in fig. 3, where a correct idea is given of the number of lymphatic vessels contained throughout the thickness of the nævus, in a perpendicular plane corresponding nearly to its centre. The horizontal position of the lymphatics is also shown here by the lines of vessels lying parallel to the line of the epidermis, not perpendicular to it; and so great is the confusion due to the cutting through of the lymphatics, that it is only in thick sections, and by using the binocular microscope, that we can see that we have to deal not with clefts or slits, but with normal lymphatic walls. That there is no alteration in the surrounding tissue is evidenced by the fact that, even although the lymphatics were distended by silver solution, and consequently

fixed in that position by the salt, as well as by the subsequent use of alcohol, yet, as soon as the distending fluids were withdrawn, the lymphatics collapsed from above downwards, as they generally do in normal skin.

In the sections made of the portion of skin treated with gold, the only noticeable feature, in connection with the nervous system, was the absence of the non-medullated nerves belonging to the subepidermic plexus, and the presence of a large number of the branched cells known as the cells of Langerhans (*c*, fig. 5) within the epidermis, where they take on the dark staining characteristic of nerve elements in successful gold preparations. The precise nature of these cells has given rise to much discussion amongst histologists. Some consider them as nervous in character; others believe them to be unpigmented pigment cells. Krause and others imagined them to be cavities representing the radicles of the lymphatics; but lately the balance of opinion has been that they are wandering cells, Ranvier being perhaps the latest exponent of this doctrine. I have, however, elsewhere shown that they are multipolar nerve cells, belonging to the subepidermic plexus of nerve fibre and cells, and that, by a hitherto unsuspected agency, they become entangled in the epidermis, broken off from the plexus, and carried through the epidermis, to be thrown off from its free surface by the natural growth of that structure. In the thin epidermis covering the great mass of the body, those cells, in normal conditions, are excessively rare. But pathologists have observed that, in inflammatory conditions of the skin, they make their appearance in great numbers. In the thick, quickly-replaced epidermis of certain surfaces, like the palms and soles, they are not so rare, but their number becomes immensely increased at the seat of any local inflammation. When, therefore, we remember the history of inflammatory attacks, erysipelatous in character, which were continually recurring on the surface of this very portion of skin, there is no reason to believe that the presence of these cells, however rare normally, has any specific importance in this disease, but, at any rate, whatever may be their importance, I think it only right to put their existence on record.

In addition to the special features in the skin under examina-

tion, we have to note that the epidermis was twice as thick as it normally is in the same region in health. When viewed from the surface, it was observed to be glistening and desquamating, and narrow but deep furrows divided the surface into irregular rectilinear figures. These furrows are shown at *g*, figs. 3 and 5, which give a better idea of their depth and character than when viewed upon the surface.

When one compares the clinical symptoms of this case, as found in the very meagre history which I have given, with the symptoms of commencing elephant leg or *elephantiasis arabum cruris*, as enumerated by the best authorities, for instance by Hebra and Kaposi, one cannot fail to be struck by the similarity between them. There is the same seat of election for the disease, the same continually recurring erysipelatous attacks, with intervals of weeks or months in the course of several years, followed each time by a certain increase in size of the leg; and there is also the painful sensation attendant upon much walking or standing erect. In short, every symptom points to an identity between the two diseases. That the lymphatics were specially and principally involved has been evident to most observers, all of whom, however, associate the disease not with lymphatic nævus, but with lymphatic varix. Dr Busey has made a very convenient compilation of the known published cases, with valuable annotations of his own upon them. I have gone over all these, both in Busey's book and in the originals, and over a number of cases which he had overlooked. All of them describe the conditions of the lymphatics as varicose, and not a single instance as a nævus. In fact, I can nowhere find that the existence of a lymphatic nævus was ever recorded or supposed; yet I believe that almost in every case lymphatic nævus was the predisposing cause. There is no reason to suppose that any case commenced as lymphatic varix, although this condition, no doubt, supervened in the course of the disease, and I have no doubt that in countries like Barbadoes, where the disease is endemic, and the earlier stages are familiar to all, histological investigation will show lymphatic nævus, existing in those early stages, as a far more effectual agent in causation than filaria, diet, or any of the numerous causes to which the disease has been assigned.

The immense development of gelatinous tissue is evidently a consequence of the presence of an enormous quantity of pure formative material in the lymphatic vessels of the nævus. Naturally the blood-supply and vessels would increase proportionately to supply the new tissue, leading to the further increased effusion of lymph, and that dilatation of the *efferent* lymphatic vessels which has been so often remarked in the more advanced conditions of elephantiasis. The intense pain which follows in all these cases is probably due to the distension, rupture, and destruction (temporary) of the subepidermic nerve plexus by the coexistent œdema. The manner in which the nerve-cells and fibres get involved in the epidermis, and ruptured there, as evidenced by the presence of the cells of Langerhans in the epidermis, shows the extent to which damage to the nervous system goes, and this damage probably reacts on the vaso-motor nerves, which are in close connection with the subepidermic plexus, leading to paralysis and dilatation of the blood-vessels, everything in fact helping on the final phenomena in the shape and size of elephant leg.

What, moreover, is true of *elephantiasis arabum cruris* is probably true of all the other forms of the disease, modified by the difference of the locality, the immense dilatation of the lymphatics, described in nearly all of these cases, being doubtless a secondary condition. Such, for example, was in all probability what happened in the case of lymphangioma, so ably illustrated and described by Mr Charles Stewart in the *Transactions of the Pathological Society of London* for 1875, page 232. The ingenious speculations of Professor Virchow on the dilatation of the lymphatics of the tongue in causing macroglossus, which he regards as a species of elephantiasis, are even more applicable to a nœvoid condition of the lymphatics of that organ similar to that which I have described in the skin.

In terminating the description of this case, I specially insist on this fact, that there is no morbid condition of the lymphatics. There is an enormous increase in number or density of the lymphatic vessels, but the walls of these vessels, and the tissues surrounding them, seem to be absolutely healthy. Nor as yet does there seem to be any tendency to dilatation or varicosities — points which differentiate this case from that recorded by Mr

Charles Stewart, and from the numerous cases enumerated by Dr Busey. The nævoid increase in number has taken place only in the deeper portion of the dermis, which normally possesses fewest lymphatics, leaving the superficial lymphatics unaltered in number. The increase, moreover, is chiefly of the valveless or collecting type of lymphatics, which is only found in the superficial portion of the plexus, the lymphatics in the deeper part of the dermis being normally well provided with valves. That they are not so in the lymphatics forming the nævus explains why the individual nævoid spots could be so readily distended with lymph when the limb was rubbed downwards against the stream. That the walls are perfectly healthy, differentiates it from the cases recorded by Kaposi and T. and C. Fox, for in both of these not only the walls of the lymphatics, but the tissues surrounding them, were so diseased and so altered, that the dilated lymphatics remained rigidly distended in excised portions of the skin, and required no special histological methods to make them visible. In my case, however, the lymphatics were collapsed, as they collapse in normal portions of skin, and but for the silver staining given to their interiors, they would have been undetectable to ordinary microscopical examination. It is this feature which has prevented Pospelow from recognising the true character of his case, which seems to have been, at all events in its histological character, almost identical with mine.

I may also note here, that the condition of the scars following the excision of the small portion of skin, showed that the irritation and disturbance of the lymphatic system caused by the wound, had led to a beneficial alteration in the same locality, so that, as a means of curing the condition, I would strongly recommend subcutaneous cutting or breaking up of the lymphatic nævi, as a means which would bring about their total obliteration, and consequently a cure of the diseased condition, and avoidance of its consequences.

III. LYMPHANGIOMA TUBEROSUM MULTIPLEX.

The chief interest connected with this case of Kaposi's was its unique character, no similar one having been met with either by himself or others. Both in the original account, in the transla-

tion, and in Kaposi's latest work, woodcuts are given of the microscopical appearances of the diseased spots ; and well it is that this was done, for the original textual description would have proved it to be unconnected with the lymphatic system. The case was that of a woman, aged 32, over whose trunk, from the pelvic to the submaxillary region, and over the back of the neck as far as the scalp, were scattered hundreds of tubercles of the size of lentils. These were of a brownish-red colour, glistening and smooth, but not scaly, and flat or moderately distended above the level of the skin. They became pale on pressure with the finger, and were recognised by the touch as firm, elastic, rounded structures, without distinct limits laterally. Imbedded in the corium, and only to be grasped in conjunction with it, they projected into the subcutaneous cellular tissue beneath, and superficially they formed the nodular elevations mentioned. These had existed from childhood.

In perpendicular section of the tumour, the corium is described as appearing perforated like a sieve. The apertures were less numerous in the upper and more in the deeper layers of the corium. In shape they were circular, oval, or irregularly rounded ; and the author says—" We are led to consider these spaces, acknowledged to be vessels, as lymphatics. We are induced to form this opinion from the shape of the lumina of the vessels, which are not uniformly cylindrical, but somewhat irregular and varicose, and from the structure of the wall, which evidently appears to consist of an intima, of a media composed of muscular fibres (*sic*), and of an adventitia strengthened by the adjacent connective tissue, arranged in dense concentric bundles, and lined on its inner surface by a distinct endothelium. Though the anatomical structure just mentioned agrees with that of the wall of a vein, we consider that the vessels in question need not be considered as a vein, but as a lymphatic." I am careful to give the words of the author ; it is needless to say that they are highly inaccurate, and they have been corrected in Kaposi's last work. The supposed muscular coat never exists in the lymphatics of the skin ; and although Kaposi has lately rendered it as "*thickened endothelium*," there can be little doubt that it was no other than the wandering cells which are found spread out on the lymphatic walls, or lying free within their cavities, in every

possible shape and in every possible stage of enlargement, by imbibition, as will be described in the next chapter. I acknowledge that, partly through the influence of this description, partly from finding the lymphatics most numerous in the lower layer of the corium, but, above all, from finding all the lymphatics circular more or less, instead of as many elongated as circular openings, I felt a difficulty in acknowledging those vessels to be lymphatics, but rather considered them to be cysts. Even now, while acknowledging them to be lymphatics, I am really led to this conclusion after making a careful examination of the tissues in the case of the Drs Fox, which certainly are lymphatics, or rather cystic dilatations in direct communication with the lymphatics, as seen at *a, i*, figs. 6 and 7.

The chief difference between this case and my own are—

1. The lymphatics were dilated and cystic; in my case they were quite normal.

2. The connective tissue of the corium was rigid and hard, leaving the openings distended; in my case the corium tissue was unaltered, and the lymphatics collapsed.

3. The spots were nodules which could be grasped and localised in the corium.

4. The tumours were situated on the trunk, not on the legs.

5. There is no history given of previous attacks of erysipelatous inflammation.

6. The spaces are filled by an albuminous material, and contained swollen wandering cells at certain localities in the diseased vessels.

In short, the two cases are evidently dissimilar; Kaposi's case being one where all the tissues were altered and diseased, while my case was merely a hypertrophy of perfectly healthy lymphatics, all the component elements of the corium being normal. The disease affecting Kaposi's case seems to have been identical with that of the Drs Fox; but there was a difference in the locality in the dermis, which gives special interest to the latter case. As, however, the Drs Fox make no reference to Kaposi's case, it is probable that they were unacquainted with it, and consequently they have failed to point out the identity in the disease, as well as the points of difference in the locality of the two cases.

IV. CASE OF LYMPHANGIECTODES.

The clinical history of this case of the Drs Fox may be perused with much profit in the original article to which reference has been given. Unfortunately, the Pathological Society did not see fit to publish also the drawings of the microscopical appearances handed in; a great mistake, as it has robbed the case of much of its importance and character, which, however, the drawings I am now able to offer (figs 6 and 7) will, I trust, restore to it. I have to offer special thanks to the Drs Fox for providing me with a portion of the excised tissue, which I cut up into sections, from which I have drawn the two figures presented, by the aid of the camera lucida.

Clinically, the case is peculiar, inasmuch as the disease of the lymphatics was co-existent with numerous and well-marked congenital venous nævi and with varicose veins. On the inner aspect of the thigh of a young man, aged 21, and for the most part entirely distinct from the venous nævi, were certain growths, isolated into several irregular raised patches, looking at a distance like warty growths, but, when more closely examined, *like frog-spawn* heaped together in masses. The earliest diseased areas were made up of a multitude of distinct, flattish, papulæ-like growths aggregated into patches; and each item of the mass looked like a tiny, sessile, pale pink wart, not bigger than a very small pin's head, with a vesicular centre. The older and larger patches were raised into irregular masses, as much as *half an inch* above the surface. About the anus, the growths might be likened to moderately exuberant condylomata. In the popliteal space, they were of the size of mulberries, and at the lower fold of the nates, there was a prominent patch, the size of the palm of the hand, and elevated half an inch in the centre of the patch. When carefully examined, these irregular patches appeared to be formed by the gradual outgrowth of the smaller points, as, indeed, was pointed out by the patient himself, each forming a minute cyst imbedded in a more or less fibrous matrix. The cyst sometimes appeared of the size of a small pea, but a certain amount of inflammation then appeared to attack the growths, and rupture the cysts. If these were punctured, a

small quantity of albuminous and clear watery fluid exuded. The patient had frequently been attacked with a sort of low fever, and latterly had had two mild attacks of lymphatic inflammation of the left foot, which became swollen, red, and painful, as if an abscess was threatening, which, however, came to nothing.

On comparing the naked-eye appearances of this case with that of Kaposi, nothing could appear more dissimilar; and yet the diseases were identical. In Kaposi's case, the small tumours felt like nodules in the lower portion of the corium; here they were like frog-spawn, raised half an inch above the surface. The difference of locality explains all the rest, for the character of the cysts and diseased dermic tissues was the same. In Kaposi's case the cysts were formed in the deeper layer of the dermis, and were thus prevented from becoming greatly distended by the surrounding dermic tissue; while on the peripheral lymphatics, or collecting lymphatics proper of the skin, they were not found at all. In the case of the Drs Fox, on the contrary, they were only formed at the extreme periphery of the lymphatics of the skin, on the outer or epidermic surface of the most superficial of the collecting lymphatics.

In general, the efferent lymphatics were not at all affected, and consequently not being kept distended by any altered dermic tissue, they had collapsed, as in normal conditions, and were therefore invisible. The preparation from which fig. 6 was drawn, was, in this respect, exceptional, and chosen on that account, for there the superficial lymphatics (*cl*) were distended like the cysts (*a*), and filled with the same coagulated albuminous contents, granular at parts, and containing fibres or needles of fibrine (*f*, fig. 7). Formed as these cysts were immediately underneath the epidermis, they received little support from the dermic tissue, but kept on distending and lifting up the epidermis above, until they appeared of the size of peas, looking like frog-spawn, and finally they burst. Of course, the whole tissue of the part became inflamed, thus accounting for the accentuated papillary condition of the epidermis, so different from the condition seen in fig. 1, which represents the normal type; and the growing cysts or ampullæ, being surrounded with a certain amount of tissue (*t*), present an appearance as if the lymphatic

had entered into a papilla, which it certainly has not, and normally never does in this region. The numerous wandering cells, which collect in masses at different localities within these ampullæ and swollen lymphatics, show conditions not uncommon, but, strange to say, unremarked by pathologists. The Drs Fox speak of this condition as vacuolation, but there is no such vacuolation as is understood by the formation of a cavity containing fluid within the cell protoplasm, to which common condition the term is generally applied. On the contrary, we have here a general swelling of the whole of the cell elements, as if caused by imbibition of fluid, by which the cell increases greatly in size and transparency, the nucleus finally becoming invisible. Various stages of this condition are seen in the cells (*sc*) drawn in fig. 7, those attached to the lymphatic wall being generally less swollen than those floating freely within the cyst or lymphatic. This power or liability of the cell to swell by imbibition was, I think, first pointed out by me last year, in the *Monatsheft für practische Dermatologie*, as being the cause and condition of the cells forming the white wheals in urticaria, but it is not at all uncommon in sections of perfectly healthy skin.

These too are the cells which, when lying flattened against the wall, have been referred to in this disease (by Kaposi in his case) as thickened endothelium, and which were previously described as muscular fibres forming a middle coat to the lymphatics.

The short personal description I have given may, I hope, serve to show that the cases of Drs Fox and Kaposi belong to one and the same morbid condition, however dissimilar their naked eye appearances are, and they therefore ought to be classed under the same head and name.

V. LYMPHANGIOMA CUTIS.

This case of Pospelow I only include, by way of completing the catalogue of lymphatic lesions bearing upon each other, and which may be confounded with each other. Pospelow, as already mentioned, confounded his case with that published by Kaposi, considering it to be the second known example; hence the above erroneous name he has applied to it. Luckily, he gives a chromo-lithographic plate of the naked eye appearances of the

skin, and a woodcut of the microscopic appearances, which latter shows it to have been a nævus, whilst its microscopical appearance was identical with the case I have described. In the naked eye appearance of the spots there seemed to be little identity. His plate shows the front of the thorax of a young woman, twenty-three years of age, the spots being comparatively few in number (only twenty-two on the chest), and widely separated from each other. Some of them were very dark in colour, being almost black, while in my case they were scarcely detectable by their colour. Pospelow also describes, in his case, the skin of the belly, face, and extremities as being of a pale yellow colour, with large sized veins showing through it. The spots looked transparent, as if filled with fluid. When cut into, the tissue had a gelatinous, mother of pearl appearance, but only the superficial portion of the wound gave off any fluid. Beyond the above sketch, it is scarcely advisable to quote further any of the speculations of Pospelow, as they are too evidently erroneous.

The foregoing are the only cases known to me of primary lesions of the lymphatics themselves, although they are often secondarily affected in connection with other diseases, but to a far less extent than is generally supposed. Into this category come the researches I have made, 1st, on the role of the lymphatics in cancerous infection;¹ and 2nd, on the condition of the lymphatics in eastern leprosy;² but as both of these researches have already been published, with copious illustrations, I shall not further refer to them here. I have also studied, at some length, the condition of the lymphatics of the skin in glanders and in gangrene, but, beyond the gorged and dilated condition of these vessels, in common with the other portions of the circulatory system, there was no evidence, that I could find, that they have any specific part in the progress of these diseases. I have likewise examined cursorily the state of the lymphatics in many other diseases of the skin, but hitherto I have made out little on which to found any observation on the pathology of these vessels in those diseases.

¹ *Archives de Physiologie*, Paris 1880, p. 284.

² *Transactions of the Pathological Society of London*, 1879, vol. xxx. p. 504.

DESCRIPTION OF PLATE XVI.

Drawings made by the aid of the camera lucida, and afterwards reduced by photography.

The following letters apply equally to all the figures: *a*, ampulla or largely dilated lymphatic; *b*, smaller ampulla; *cl*, collecting lymphatics; *c*, cells of Langerhans; *sc*, swollen wandering cells; *d*, dermis; *e*, epidermis; *el*, efferent lymphatics; *f*, fibrine; *fc*, fat cells; *g*, transverse section through furrows in epidermis; *h*, hair follicles; *s*, sweat gland; *v*, blood-vessels.

Fig. 1. View of the lymphatics in a thin perpendicular section of the skin of the breast of a man, showing the normal size and distribution of these vessels, $\frac{1}{10}$.

Fig. 2. View of the whole of the superficial portion of the normal lymphatics of the human skin, in a thick horizontal section from the leg, from a specimen injected with dilute solution of silver, the darker portions being the more superficial, $\frac{1}{20}$.

Fig. 3. Perpendicular section through a lymphatic nœvus of the skin of the leg, the lymphatics having previously been injected with dilute solution of silver, $\frac{1}{25}$.

Fig. 4. Horizontal section through the upper portion of a lymphatic nœvus of the skin, the lymphatics injected with silver solution, $\frac{1}{20}$.

Fig. 5. Greatly magnified view of the superficial portion of a perpendicular section through a lymphatic nœvus of the skin, the tissue having been treated with chloride of gold, to show the condition of the nerve elements, $\frac{1}{200}$.

Fig. 6. View, under a low power, of the early condition of the dilated lymphatics of the skin, seen in perpendicular section, from a case of lymphangiectodes. At *i* the collecting lymphatic *cl* is seen to be in direct communication with the large ampulla *a*, $\frac{1}{10}$.

Fig. 7. Greatly magnified view of a perpendicular section through the skin, in a case of lymphangiectodes (next section to that seen in fig. 6, and corresponding to *a*, *b* in that section), $\frac{1}{150}$.

NOTES ON THE VISCERA OF THE PORPOISE (*Phocaena communis*) AND WHITE-BEAKED DOLPHIN (*Delphinus albirostris*). By Professor CLELAND, F.R.S., Glasgow.

THE following notes are founded on specimens prepared from viscera of the porpoise and the white-beaked dolphin placed at my disposal by Mr J. M. Campbell, who described the specimen of the white-beaked dolphin in question in *The Scottish Naturalist*, January 1881.

Stomach.—The stomach of the white-beaked dolphin differs from that of the porpoise in various points of detail. The communication of the horny-lined panch with the rugose digestive or second stomach, instead of being so narrow as it is in the porpoise, is like that figured and described by Professor Turner¹ in the pilot whale (*Globiocephalus*), an aperture more nearly approaching in size to the œsophageal (though less than it), and capable of allowing food to pass directly into the digestive stomach from the œsophagus without entering the panch.

Like the porpoise, the white-beaked dolphin has but one small compartment intervening between the rugose digestive pouch and the elongated pyloric compartment, while in the pilot whale Professor Turner points out that there are two. But this small compartment bends backwards at its commencement, then turns forwards before opening into the pyloric tube, so that it only wants the constriction between those two parts to make it like the third and fourth stomachs of the pilot whale. It differs also from the porpoise, and resembles the pilot whale in the position of its entrance and exit. In the porpoise, the entrance to the third stomach is toward the lower part of the rugose digestive pouch, but in the white-beaked dolphin and, according to Turner, in the pilot whale, it is considerably nearer the upper than the lower part. In the porpoise the third stomach is globose;² a

¹ *Journ. Anat. and Phys.*, Nov. 1867 and Nov. 1868.

² This is correctly stated by Flower, *Med. Times and Gazette*, Oct. 19, 1872; but Huxley, describing the porpoise, *Manual of Anatomy of Vertebrated Animals*, 1871, p. 407, states that "a narrow and curved canal" leads from the second stomach to that which, like some other authors, he terms the third stomach, namely, what I call the pyloric tube or compartment. Professor Flower points

straight rod will pass through the middle of it if made to enter by the one aperture and emerge by the other; and the pyloric compartment has a dilatation at its commencement placed below the aperture which leads into it; but in the white-beaked dolphin and the pilot whale the initial dilatation of the pyloric compartment is placed above the aperture which leads into it. I notice, however, that the elongated compartment which I term pyloric is not so dilated in my white-beaked-dolphin as it is represented in the pilot whale. Beyond doubt the valve in which this compartment ends is the true pyloric valve, and the dilatation beyond is a duodenal bulb with the opening of the bile duct not separated from it by any notable constriction. The pyloric valve is always of circular structure, capable of complete occlusion, and above the bile duct.

The comprehension of the cetacean as of other complex stomachs must be arrived at by considering the elements which go to form a stomach. The stomach is the expanded commencement of the abdominal canal as far as the suprabiliary valve, that is, the pylorus. There are at least two fishes of totally divergent kinds which have the bile duct opening into the receptive dilatation of the alimentary canal: they are the *Chimæra* and the *Orthragoriscus*. In describing the latter, a number of years ago, I own that I spoke of the bile duct opening into the stomach; but the expression is morphologically inaccurate; and it is with admiration that I notice how Stannius¹ avoids it in describing *Chimæra*, stating that the digestive tube is traced without intervention of stomach into a dilatation, the duodenum, into which the ductus choledochus opens. On the other hand, one recognises in the sharks and rays, from the position of the bile duct and pancreatic duct, that the tight valve above the spiral-valved intestine is pylorus, and that the narrower tube above this, sometimes mistaken for small intestine, is no such thing, but a pyloric compartment of the stomach. True, in some kinds, such as in *Scyllium* and *Lamna*, it is separated by a constriction from the more obvious part of the out, in the same place, how different the passage from the digestive to the pyloric compartment is in different Delphinoidea, divided in different species by different numbers of constrictions. This is why it is advisable to name the three great compartments by distinctive rather than numerical designations.

¹ *Die Wirbelthiere*, 2^{te} Auflage, erstes Heft, 193.

stomach, but in the skate and the *Acanthias* it is not so cut off, but is quite continuous with the great dilatation, and narrows in a gradual manner to its termination. That pyloric division of the shark's stomach is precisely similar to the pyloric compartment, as I have termed it, in the cetacean.

The next point to consider in the morphology of stomachs is that they tend to curve and turn over to the right side, so as to have the pylorus to the right, and the side which had been primitively to the left turned so as to look in the ventral direction. These circumstances depend, first, on the adhesion of the liver to the cephalad wall of the abdomen, notwithstanding that, so far as its ducts are concerned, it is developed from the duodenum, and therefore further from the head than is the stomach; secondly, the late development of the œsophagus, which, elongating with the displacement of the thoracic viscera, pushes the œsophageal end of the stomach before it. But, besides these circumstances, there is one other which is of later origin and much less constant,—perhaps I might say exclusively Mammalian,—the tendency of the commencement of the convexity of the curve to project to the left (or morphologically dorsal) side as a cæcal pouch with circular muscular fibres of its own. This pouch is remarkably developed in families widely separate, as in some of the bats, in the peccary, in the ruminants, in the syrenia, and the cetacea. The line of demarcation between the secreting mucous membrane and the squamous epithelium prolonged down from the œsophagus differs in different mammals; notably in the horse, only the pyloric half is a stomach of digestion, while in the rat a similar disposition coexists with a larger cardiac cul-de-sac. Now it is plain, and in the young subject can be easily seen, that the ruminant panch is simply a cardiac fossa with a letter-S curvature. The reticulum and omasum are mere sacculations of the part immediately beyond, lined, like it, with firm epithelium; while only the abomasum has the mucous membrane specially thick and soft in connection with the secretion of gastric juice. The porpoise and dolphin have, however, compartments beyond the specially active secreting part, a development of that part which in the dog, and probably in the human subject, is not so actively secreting as the part in the middle district; compartments not differing par-

ticularly from the duodenum in the appearance of their mucous membrane: and in the possession of these they resemble the sharks. In a large porbeagle shark I notice that the digestive cavity has permanent longitudinal rugæ zigzagged in their course like those of the dolphin, and of proportional magnitude, while the opening into the smooth-walled pyloric tube is only large enough to admit a goose quill. Manifestly the huge masses received into this great sac are digested down into chyme before passing into the pyloric tube. This seems to be what happens also in the case of the porpoise and dolphins; and it seems not improbable that their third and subsequent compartments are mainly connected with absorption of fluids before admixture of the bile.¹

The white-beaked dolphin's panch was full of perfectly clean whiting bones, and a quite clean whiting's vertebra was found in its mouth, but not a bone was found in any of the subsequent stomachic compartments, nor a vestige of bone in the whole length of the intestine. That clean bones are thus accumulated in large numbers in the first stomachic cavity of different species is mentioned in Home's *Lectures on Comparative Anatomy*, quoted in the Catalogue of the Royal College of Surgeons in London;² and it is further mentioned that sometimes the earth is absorbed, so that only the soft parts of the bones remain—the only parts which could pass into the next compartment. It seems possible, however, that they may be got rid of partly by vomiting. Fish bones are easily deprived of their earthy matter by acid, and this matter dissolved may pass on into the second stomach; but if the decalcified bones passed on I think I would have observed them. It may be that in the white-beaked dolphin and the pilot whale food sometimes passes at once into the digestive rugose sac; but the exit from this is constricted; and it is worthy of note that while such a thing cannot happen in the porpoise, on account of the small and guarded character of entrance into

¹ To complete this rough sketch of the morphology of the stomach, it is perhaps necessary to add a reference to the occurrence of special local additions of peculiar secreting structure, such as the proventricular glands of the bird introduced prior to the gizzard, the gizzard being homologous with the panch; also the cardiac gland of the syrenians, and perhaps the gland on the great curvature of the beaver's stomach.

² *Physiological Series, Comp. Anat.*, vol. i. p. 175.

the second sac, it is in the others, in which such a thing may happen, that the exit of the second sac is narrowest, and the communication with the pyloric compartment most indirect.

It may be noted that in the peccary, which has the panch separated by a constriction guarded with huge folds of horny epithelium from the digestive cavity beyond, the fundus of the cul-de-sac of the panch, projecting in form of two cornua, is lined with a strip of soft mucous membrane, not to be compared in thickness with the digestive pyloric compartment; and it seems quite possible that this mucous membrane may have such an absorptive function as I have suggested for the pyloric compartment of the cetaceous stomach. Professor Flower¹ attracts attention to the rugæ of the second stomach of the porpoise being longitudinal, with secondary ridges coming off from them,² intercalating with similar ridges given off by the adjacent longitudinal rugæ, and he notes it as a peculiarity not found in most other species. In the white-beaked dolphin the main rugæ are not so regularly longitudinal, but run into one another more frequently, and are zigzagged in their course like those of the porbeagle shark.

Intestine.—In the white-beaked dolphin the bile duct in its last inch and a half of length is straight, with strong muscular walls adherent to the duodenal bulb. Above this it is sacculated in a remarkable manner, reminding one of Camper's figure of the bile duct of the elephant. The intestine has longitudinal rugæ most developed at the unattached side, as has the porpoise; but it has also what the porpoise has not, thickly-set transverse redundancies of the mucous membrane, like abortive but thickly-set valvulæ conniventes—a transition towards those much more marked folds which have been described in *Hyperoodon*.

Toward the rectal end the mucous membrane gets thicker and more irregular, till above the constriction of the rectum it ends in a dilated part, with ridges dividing the surface of the mucous membrane into irregular recesses, these subdivided by smaller ridges, and between the latter an appearance of small

¹ *Medical Times and Gazette*, October 19, 1872.

² I notice similar secondary rugæ coming from the sides of some of the main longitudinal rugæ of the seal's stomach.

pores.¹ In the porpoise there is no such expansion, and no such change in the appearance of the rugæ, which extend nearly to the prolonged constriction of the sphincter. This contrast of the rectum of porpoise and that of dolphin appears to be illustrated in the Museum of the Royal College of Surgeons, London.²

Heart and Great Vessels.—One of the most notable circumstances in the heart of the porpoise is the small size of the cusps of the auriculo-ventricular valves and the high position of the muscoli papillares, the bases of which are situated about midway between the base and apex of the ventricles. Another feature is the copious plexus of veins flowing into the coronary trunk, which surround the valves of Valsalva of the pulmonary artery, and extend upwards on its walls. Noting this a number of years ago, I was interested to find that the walls of the pulmonary artery in man are likewise surrounded with veins which terminate in the coronary vein, only they are not so conspicuous. In the porpoise the ductus arteriosus is shut, as it is stated by Turner to be also in *Globiocephalus*; but in the white-beaked dolphin it is open, admitting an *Echidna* spine, and is guarded on the cardiac side of its aortic termination by a curious transverse fold or valve, involving part of the middle coat of the artery. This interests me the more, as my late demonstrator, Dr William Allen, had previous to these observations found a similar valve in exactly the same position in a human subject, which had the duct closed, as usual. In the porpoise I see only the faintest trace of such a fold, and the duct is closed. It is curious that in Cetaceans, as in other aquatic mammals, the ductus arteriosus should be sometimes closed and sometimes open. In the seal it is large; in the otter it is completely obliterated.

It is so difficult to estimate the amount of blood in the body of any animal, that one scarcely cares to remark on the subject; but in the seal, the porpoise, and dolphin, the amount in proportion to the size of the animal does seem enormous; and it is worth observing that, with large venous reservoirs as in the seal, and arterial and venous reservoirs as in the dolphins, an amount of blood superfluous to land animals becomes useful as con-

¹ The whole arrangement recalls Dr Murie's beautiful figure of the colon of *Globiocephalus*, in the *Trans. Zool. Soc. Lond.*, vol. viii., plate xxxiv.

² *Op. cit.*, vol. i. p. 221.

veying oxygen to the tissues for a greater length of time in diving.

Respiratory Organs.—I beg to verify the observation of Mr Howes¹ that the cartilages which together with the epiglottis are so remarkably elongated in porpoises are not arytenoids, but articulate with them, and may be regarded as cartilages of Wrisberg. I cannot find that the remarkable glandular arrangement of the larynx has been noticed. But in both porpoise and white-beaked dolphin there is a huge mass of lobulated gland substance intervening between the lower border of the thyroid cartilage and the front of the cricoid, which is completely divided in the middle line. Then another mass of glands occupies the hollow of the round middle part of the peculiarly shaped thyroid cartilage, and when one looks at the interior of the larynx it is seen that there is a very slight transverse ridge in front corresponding to the position where vocal cords might be expected to be attached; and above and below this there are irregular longitudinal ridges, in the recesses between which, probably, the glands open. It is easy to understand the necessity of having the larynx lubricated with abundant mucus in animals which have such forcible expiratory movements.

In connection with the lungs, besides the well-known peculiarities described by John Hunter and later writers, there may be mentioned the presence of a remarkable fringe of redundant pleura, more than a quarter of an inch in breadth, along the sharp sternal and diaphragmatic margins of the lungs. The great thickness of the pleura enabled me to strip it entire with the greatest ease from one of the lungs of the porpoise. The fringe was then found to remain firm, not separating into two layers, and the pleura was observed to have a vascular supply distinct from the contained organ, with the stems diverging from the root of the lung.

In both porpoise and white-beaked dolphin, although the lungs are not divided into lobes as in other mammals, there is at the apex of the right lung a notable sulcus in which lies the vena azygos; so that the lobe on the dorsal side of the sulcus corresponds with the supernumerary lobe occasionally found in man.

¹ *Journal of Anatomy and Physiology*, July, 1880.

Male Genito-urinary Organs.—These have a general similarity in the two species. In both the testes are elongated, and each is connected with the ventral end of the corresponding pelvic bone by a fibrous band, crossed at its pelvic end by the vas deferens, and representing the upper division of the gubernaculum in the human foetus. There is a rete mirabile of spermatic arteries which come off, crowded together from the aorta, and are probably persistent arteries of the Wolffian body.

In the white-beaked dolphin there are four openings into the floor of the first part of the urethra. The two upper are the openings of the vasa deferentia; and immediately beyond these, are two larger openings distinct one from the other, and both leading up into a single sinus pocularis. This arrangement is of great interest, exhibiting in the male adult a condition passed through as a stage of development in the female, in which the vagina remains double, while the oviducts are already united to form one uterine cavity. In the porpoise the disposition is not the same; the urethra at this part expands, and has a longitudinal fold on each side, while between the folds the floor is convex, and exhibits two oblique openings of the vasa deferens. Then immediately below and parallel to these are two oblique fissures which meet in the middle line, forming a single opening like the Greek capital lambda, and leading up to the sinus pocularis.

The penis also is different in the two animals. In the porpoise the corpora cavernosa, which are thoroughly fused in one, thin away toward the extremity, leaving only a tough fibrous structure, continuous with their sheath, to support about two inches of the urethra. I find here no plexus of veins or glands of any sort such as described in the article "Cetacea" in the *Cyclopædia of Anatomy and Physiology*. But in the white-beaked dolphin, the combined corpora cavernosa about two inches from the free extremity are suddenly compressed as if by the removal of more than half their substance on the ventral side, and then expand again and taper to the point. It is such an arrangement as will allow the slender end to be folded down on meeting with resistance in the erect condition, and doubtless such is the mode of intromission in both species. A large lacuna magna exists in both, and it seems obvious that this can only be effectually emptied by the grasp of the sphincter vaginae in withdrawal.

COSTAL AND STERNAL ASYMMETRY. By W. ARBUTHNOTT LANE, M.S., F.R.C.S., *Demonstrator of Anatomy to Guy's Hospital, Assistant Surgeon to the Hospital for Sick Children, Great Ormond Street.*

WHILE making sections through a number of sterna, I obtained a specimen, Case 1, in which the manubrium has an oblique lower margin, its direction being from above downwards to the left. The gladiolus presents seven bony centres, each somewhat hexagonal in shape. They are arranged in two vertical lines, four being placed on the right side and three on the left. Those on the left side alternate in position with those on the right. The attachment of the 1st costal cartilage to the manubrium is quite normal. Owing to the obliquity of the lower margin of the manubrium, the 2nd costal cartilage on the left side is attached to the sternum on a level considerably lower than that on the right. Between the lower part of the inner extremity of this cartilage and the gladiolus is seen on either side an articular cavity. This is the first articular cavity to form in connection with the sternum and its cartilages.¹ Under the microscope the early stage of the process of cavity formation could be seen in the upper portion of the 2nd cartilage, where it joined the manubrium, and in the cartilage connecting the manubrium and gladiolus. Owing to the alternation of the bony plates in the gladiolus, and to the fact that the cartilages of the ribs are continuous with the cartilages intervening between these plates, the 3rd, 4th, and 5th costal cartilages on the left side are attached to the mesosternum at a much lower level than those on the right side. The 6th and 7th cartilages are on the same level on both sides.

This condition of costal asymmetry is always accompanied by an asymmetrical arrangement of the sternal centra. In a sternum which was obtained from a foetus aged two months, Case 2, I found the 2nd and 3rd costal cartilages were nearer to one another than those on the left side. This would lead one to suppose that the asymmetrical arrangement of the bony centra

¹ "One Mode of Fracture of the Sternum," *Trans. of Path. Society*, 1884.

was at least not the whole cause of this condition. Mr Kitchin Parker, in his complete monograph,¹ describes "the sternum as being broad in flat-chested men, and those of the mesosternal region are ossified by symmetrical pleurostea. The whole of the mesosternum is thus ossified in the orang, and it has no appearance of a præ- or meso- central cleft." In fig. 16, plate xxx. he figures the sternum of a young orang (*Pithecus satyrus*), which resembles almost exactly the arrangement in Case 1 in this paper, except that in it there are four instead of three centra in the left half of the gladiolus. I fail also to see how the pleurostea are symmetrical, as they seem to alternate in his drawing exactly as they do in my specimen. Neither in the text nor in the drawing does he make any difference in the level of the costal cartilages at their attachment to the sternum. Those in the drawing are on the same level on both sides, and they are attached internally to the bony segments on the left side and are not to the cartilage intervening between these segments. I find no mention of this asymmetrical condition in any work on comparative anatomy.

Examining the skeletons in the Museum of the Royal College of Surgeons I was able to detect no instance of costal or sternal asymmetry in any of the quadrupeds. Among the orang-utans I found very frequently a difference in the level of the cartilages on either side, and accompanying this an asymmetrical arrangement of the sternal centres. In all these skeletons the costal cartilages articulated with the cartilage intervening between the bony centres of ossification. The side on which the cartilages were higher seemed to depend in many cases on the direction of the lower margin of the manubrium. In specimen 50 (*Pithecus satyrus*) the gladiolus presents eight centres. The cartilages on the right side are higher than those on the left. In specimen 48 those on the left are lower than those on the right side. The two lowest pleurostea have fused to form a single bone. In specimen 37, the left 3rd, 4th, and 5th costal cartilages are lower than those on the right side. The four lowest pleurostea have fused, also the second pair.

In some specimens, as in 38 and 40, there is no costal asymmetry. This irregularity is not confined to the orang-utans.

¹ *Monograph on the Structure and Development of the Shoulder Girdle and Sternum in Vertebrata*, Ray Society.

Specimen 29 (*Troglodytes gorilla*) shows the manubrium fused with the right upper pleurostean of the gladiolus. The lowest pair had also joined, so that only two are free on the right and three on the left side. This fusion of the manubrium with the upper centra of the gladiolus is by no means infrequent among the Primates. In man I believe the presence of an articulation between the manubrium and gladiolus in man is due chiefly to the rotation of the manubrium round an antero-posterior axis, produced by the immensely powerful leverage exerted by the clavicle upon the end of the first rib and costal cartilage.

I have frequently noticed this asymmetry of the costal cartilages in the *post-mortem* room and dissecting room of Guy's Hospital. Usually the left costal cartilages are on a lower level than the right. It may be a partial asymmetry, being limited to one or two pairs of cartilages, or it may be almost universal, affecting every pair with the exception of the first. No. 1043¹⁵ in the Guy's Hospital Museum, is an example of the last condition, and is particularly interesting, as on the left side there is a slight fusion of the 1st and 2nd costal cartilages. It presents a fracture of the gladiolus near its upper margin. In it, though the lower margin of the manubrium is quite transverse, the left second costal cartilage is attached chiefly to the manubrium, so as to be on a higher level than that on the right side. The 3rd, 4th, 5th, and 6th cartilages on the right side are attached to the sternum on a level considerably below those on the left. The gladiolus presents in its lower part a foramen in the middle line, another indication of mal-development.

Another character I would point out in this specimen is one which I have alluded to elsewhere,¹ and that is the increased relative length of the gladiolus in cases of fusion of the upper two ribs or cartilages. I would refer again to the same paper to show that asymmetry of the costal cartilages was present in all the cases of fusion of the 1st and 2nd cartilages which I there described (see fig. 6, fig. 7, fig. 8, in *Guy's Hospital Reports*), and in two of the cases of cervical ribs (fig. 1, or in the case of a silvery gibbon). How far these conditions stand to one another, in the relation of cause and effect is difficult to decide. Certainly, in the case of cervical ribs I am inclined to regard

¹ "Cervical and Bicipital Ribs in Man," *Guy's Hospital Reports*, 1883.

the costal asymmetry as merely a coincidence. Why this asymmetry should appear in many of the primates, and then almost disappear in man, is a curious and an interesting problem, in the explanation of which I will, at present, not venture a hypothesis. At the same time, besides the mere interesting aspect of the condition, its clinical importance must not be lost sight of. Only the other day a well-known physician remarked to me that he occasionally came across cases in which he found himself somewhat at a loss to decide on the identity of a particular rib. In some of the cases which I have examined, the difference in the level of ribs in the mammary line has been considerable, amounting even to three-quarters of an inch (as in fig. 8, "Cervical and Bicipital Ribs in Man," *Guy's Reports*, 1883). This would modify very markedly the position of the apex beat, and might materially affect an opinion in a life insurance case.

Anatomical Notices.

MALFORMATION OF INCISOR TEETH.

By ROBERT KIRK, M.D.

ON November 12, 1883, I was called to extract the milk incisor teeth of a little girl, aged 6½, on account of the permanent teeth beginning to force themselves through the gums. The upper incisors were quite normal, but a casual glance showed that there were six lower incisors. The right lateral incisor was normal, but the right middle incisor was twice its customary breadth, and divided longitudinally into two halves by a deep groove, extending from the middle of the cutting edge of the crown to the lower end of what remained of the fang, giving the appearance of two separate teeth fused together. The root of this tooth was unfortunately so much absorbed, that its condition, whether single or double originally, could not be made out.

The left middle incisor was normal, and its fang was about one half absorbed. The left lateral incisor was twice its ordinary breadth, and longitudinally divided by a groove like the right middle incisor, and the root was unabsorbed and distinctly bifid for at least a third of its length. The permanent teeth have since appeared, and they present no abnormality.

NOTE ON A SPECIMEN OF BICIPITAL RIB. By J. HALLIDAY SCOTT, M.D., *Professor of Anatomy, University, Dunedin, Otago.*

IN a subject recently dissected in my Practical Anatomy rooms, I obtained a specimen of abnormal rib, a note of which may be of interest in connection with the specimens described and figured by Professor Turner in this *Journal*, April 1883. The ribs were the first and second thoracic of the right side, and were normal in their position, articulations to the spine and to the sternum through their costal cartilages. But, instead of running independently to their sternal ends, they united about 1½ inch beyond the proper tubercle into a plate of bone, somewhat more than 2 inches broad at its widest part. The union took place immediately to the vertebral side of the groove for the subclavian artery, which groove, as well as the tubercle for the scalenus anticus, was well marked on the first costal arch element of the plate of bone. The rough surface for the attachment of the serratus magnus was also distinctly marked on that part of the plate of bone which corresponded to the second costal arch. The broad plate

bifurcated anteriorly into two processes, each of which was continued into a costal cartilage.

The ribs of the left side were normal, and the height and appearance of both sides of the thorax were the same. The abnormal condition having been observed whilst the subject was undergoing dissection, there is, of course, no doubt that the ribs affected were the upper two right thoracic ribs.

[I have drawn up this statement partly from the notes made by Professor Scott in a letter to me, in which he briefly records the chief points of the case, and partly from a water colour drawing which he encloses. The preparation in the breadth of the plate of bone formed by the fusion of the two shafts closely approximates to the specimen, figured by Knox (fig. 5), and referred to by me on p. 395 of my paper on bicipital ribs, above quoted, as now in the Anatomical Museum of the University of Edinburgh. This specimen of Professor Scott's differs, however, from Knox's, and from any others that I have seen, in having the union of the shafts of the two ribs much closer to the subclavian groove, and further away from the tubercles. The extent of the fused shafts was, judging from the drawing, not more than 2 inches, whilst in Knox's specimen it was nearly 3 inches. Thus, as Dr Scott had, from an expression in his letter, obviously recognised, his specimen was a link between those which I had described and the normal arrangement.—W. TURNER.]

NOTE ON THE NERVE SUPPLY OF THE STERNO-CLAVICULAR ARTICULATION. By DAVID HEPBURN, M.B. C.M., *Demonstrator of Anatomy, University of Edinburgh.*

As the text-books give no information on the nerve supply of the sterno-clavicular joint, the following note of a dissection made a few weeks ago may be of interest. A small nerve was found entering the sterno-clavicular articulation. It had the following relations :—

The cutaneous descending branches of the superficial division of the cervical plexus made their appearance in the usual position, viz., in the space between the sterno-mastoid and trapezius muscles. They passed downwards in a group until they reached a point about an inch and a half above the central portion of the shaft of the clavicle, where the several branches diverged from each other, and assumed their distinctive positions as acromial, clavicular, and sternal.

On examining the sternal branch it was found to reach the anterior aspect of the shaft of the clavicle two and a half inches from its inner extremity. At this point it changed its direction abruptly, passing towards the mesial line of the body, and lying on the clavicle for a short distance prior to its distribution over the pectoral region at a level below the clavicle. As it lay on the clavicle a slender twig was given off. This ran on the bone towards its inner end, and was found to pass beneath the outer border of the anterior sterno-clavicular ligament, becoming lost on the synovial membrane of the joint.

RECTUM OPENING INTO THE MEMBRANOUS PART OF
THE MALE URETHRA. (PLATE XVII.)

DR WILLIAM CRAIG has recently communicated to the *Edinburgh Medical Journal*, March 1884, a very interesting case of malformation in a male infant, in which the child passed its fæces through the urethra. In the perinæum there was a well-marked raphe, and a depression in the region of the anus, but no trace of an opening. The penis, testicles, and scrotum were normal. An exploratory incision, with a view to make an artificial anus, was made by Mr Joseph Bell, but without any trace of the rectum being found. The child continued to pass fæces by the urethra, and died eighteen days after birth.

On a *post-mortem* examination the following condition of the parts was seen :—In the middle line of the perinæum, instead of an anus, there was a depression or *cul-de-sac*, of sufficient depth to admit the greater part of the distal phalanx of the little finger. The internal organs were exposed by a crucial incision, and inspected *in situ*. Above the pelvis they were normal and healthy. The ascending and transverse colon contained some soft semi-fluid feculent matter, bright yellow in colour. The descending colon and the pelvic organs, including the penis, scrotum, and testicles, were removed *en masse*, and preserved for some weeks in chloral. They were afterwards transferred to strong spirit for a few days to harden. A mesial section was made through the penis, bladder, and lower part of the rectum. The bladder wall was slightly hypertrophied. There was no communication between the rectum and the bladder, but in front of the prostate gland the rectum entered the membranous portion of the urethra. The first and second parts of the rectum were well developed, the latter being somewhat dilated behind the place where it opened into the membranous part of the urethra. The third portion of the rectum was completely undeveloped.

Dr Craig comments on this case as follows :—

“In cases of simple imperforate anus the case is easily explained by a reference to the mode of development of the anal opening, namely, by ‘invagination of the outer surface, and the opening of a communication between it and the intestine.’ True, we have here an imperforate anus, but we have something more; there is the absence of the third part of the rectum, and therefore this explanation cannot hold good in the case before us. I am inclined to the view that, in this case there did take place, to a certain extent, at least, this ‘invagination of the outer surface,’ for there is a well-marked depression in the region of the anus; and if the lower portion of the rectum had been fully developed, the probability is that we would not have had even a case of imperforate anus on this occasion. There is evidently a considerable portion of the lower bowel not developed, besides the communication existing between the rectum and urethra. By a reference to the drawing it will be seen that the rectum is prolonged into a narrow tube, which terminates in the membranous portion of the urethra. This can best be explained by a reference to the development of these parts. At a very early period of embryonic life (about the fourth week) there is

'a common opening for the intestine, the generative, and the urinary organs, i.e., a *cloacal* aperture.' By the development of tissue a septum is formed between the *sinus uro-genitalis* and the intestine. In the present case this septum was not fully developed, and so we have the remains of a condition, existing in early embryonic life, persistent by this opening between the bowel and urethra. Regarding the non-development of the third portion of the rectum I am unable to offer any explanation.

"It thus appears that this rare malformation has been caused partly by the want of development of the tissue which forms the septum between the *sinus uro-genitalis* and the intestine, partly also by the want of development of the lower portion of the rectum, and possibly also to a certain extent by the invagination of tissue which forms the anal opening not having proceeded far enough.

"This case is one exceedingly rare. I am not aware of any case exactly similar having occurred. Dr Maxwell Ross has drawn my attention to the fact that Holmes, in his *System of Surgery* (vol. v. page 814, 2nd edition), states that the rectum may communicate with the urinary tract, but relates no cases in detail. He says that 'communications between the lower end of the bowel and the male urinary organs, with imperforate anus, constitute the most troublesome variety' of imperforate anus. He states, farther, that the communication may be either with the urethra or bladder, in which case he expresses the belief that it can be reached from the perinæum.

"Dr Maxwell Ross has also drawn my attention to the fact that the *Medical Times and Gazette* of 22nd September 1877 records a case not exactly identical, but presenting features in many respects resembling this one. It is designated, 'Case of Imperforate Anus and Fistulous Opening into the Bladder.' It is from the *Australian Medical Journal* of March of that year, and is as follows:—'A male child was brought to Dr Rowan for advice (11th April 1876) three days after birth, having an imperforate anus, and the abdomen being very distended and tender. No depression or other sign of the position of the anus existed, and an incision was made at the centre of the fundament large enough to admit the index finger as a guide. On cutting to a depth of about two inches and a half, a fluctuation in the line of the rectum could be felt. On opening this fluctuating mass, a large quantity of meconium and gas escaped, with immediate relief. Oiled lint was passed into the wound, and replaced every morning for about a week, after which a bougie was introduced every second or third day to keep the aperture open. Nothing was heard of the case from May until February 1, 1877, when the passage was found closed, so that a probe could not be introduced. For two months nothing had passed by this aperture, the motions having come away during that time by the penis until the day before the child's arrival, when the foreskin had become so much closed that it could only pass water with great pain and difficulty. This was remedied by circumcision, and on 6th February an attempt was successfully made to restore the natural passage. Since the second operation no fæces or flatus passed by the penis since two days after the operation.

"This case differs in several particulars from the one we are now considering. It was eight months after the birth of the child that fæces first came through the penis, from which we naturally conclude that the opening between the bowel and the bladder was not congenital. In my case there was a well-marked anal depression, but no trace of that in Dr Rowan's case; and I am inclined to the belief that in his case the rectum was more fully developed in its lowest part, which would greatly aid the success of the operation."

Through the courtesy of Dr Craig we are enabled to reproduce the plate in illustration of this interesting malformation.

THE FŒTAL MEMBRANES OF THE OPOSSUM AND OTHER MARSUPIALS.

DR HENRY F. OSBORN has recorded in the *Quarterly Journal of Microscopical Science*, July 1883, observations on the foetal membranes in the Marsupialia, in the course of which he states that the following may be regarded as fairly well-established facts:—

"1. That the yolk-sac at an early stage spreads over the inner surface of the subzonal membrane, forming a disc-like chorion, which in the kangaroo and opossum is bound by the sinus terminalis. This chorion may become extensive in the later stages. The subzonal epithelium then gives rise to hollow conical upgrowths of columnar cells. From the epithelium of the yolk-sac there arise papillæ, which become vascular, while the subzonal cells become very much flattened. The rudimentary villi thus formed, in the early opossum and kangaroo embryos, are thickly distributed over the area surrounded by the sinus terminalis, but in other forms they may extend beyond this area.

"2. The allantois arises in the same way as in the Placentalia at quite an early stage of development, and soon becomes vascular. In the kangaroo, if it unites with the subzonal membrane at all, it is only in the later period of gestation. In the opossum it develops rapidly, so that a brief union with the subzonal membrane before birth is not improbable. In the unknown Marsupial, described in the paper, this union seems actually to have taken place.

"3. The amnion, as in the Placentalia, in all cases invests the embryo.

"4. One or two long furrows are formed along the lower internal border of the uterus in the kangaroo and opossum. In close contact with one of these in the opossum is placed the villous chorionic disc of each of the numerous foetuses; the remaining portions of the subzonal membrane are free. The embryo is undoubtedly retained in this position throughout intra-uterine life. During this period the opossum is known to keep remarkably quiet, so that the uterus is

little disturbed, and is most of the time in a horizontal position.¹ The presence of foetal villi is strong evidence by analogy of the presence of minute crypts on the inner wall of the uterus.

“It is an undoubted inference from the above facts that in the early stages of Marsupial development the vessels of the yolk-sac not only are the channels for conveying the maternal nutriment to the foetus, but that this function is performed by capillaries distributed in low villi, and separated from the maternal structures, whatever the arrangement of the latter may be, by an extremely thin layer of subzonal epithelium. It is evident that these villi are altogether similar in structure to those which are found over the allantoic chorion of the pig;² the difference is merely one of degree. The rudimentary mechanism is sufficient to support the rapid growth of the embryo opossum, which at birth is completely equipped with all the necessary respiratory and digestive apparatus acquired during an intra-uterine period barely exceeding two weeks.³ This could not be effected if the absorbent villous area were shifting about from one part of the uterus to another. This fixity of position must have been an important step towards the establishment of an allantoic placenta.”

¹ “The fact noticed by several observers, that the females are found in plenty immediately after the birth of the young, would seem to indicate that they had been hiding for some time.”

² “See Turner, *Journal of Anat. and Phys.*, xi. p. 34.”

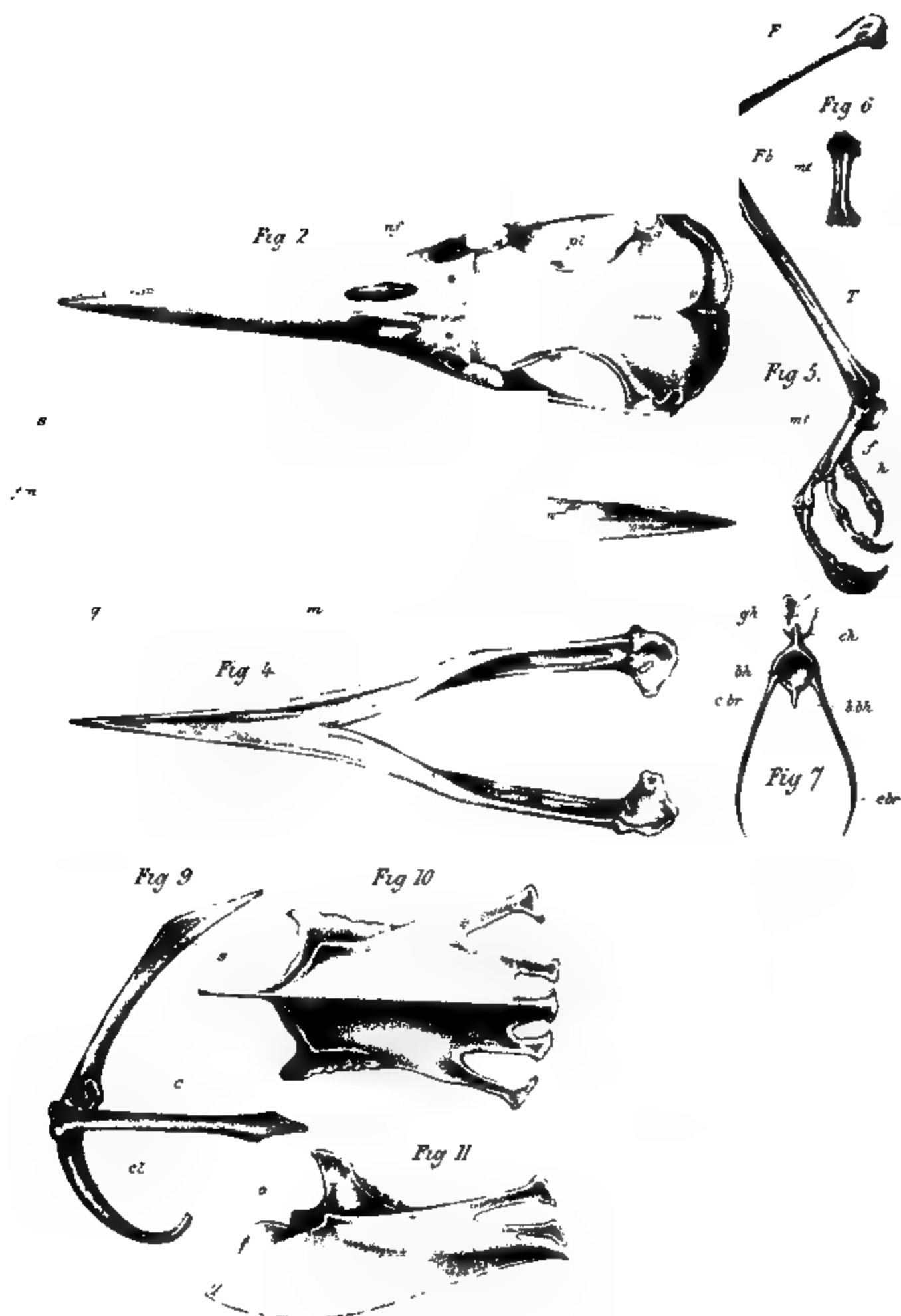
³ “The feebleness of the young at birth has been exaggerated. The opossum young weigh from four to five grams, and in their bent position are one-half an inch long. All the bodily functions are fully in action, the fore limbs are strong and provided with claws, the young are taken in the mouth of the mother from the vulva and placed in the pouch, probably close to one of the nipples, the grasping of which is instinctive. They will retake the nipples after removal from the pouch and exposure for several hours.”



Fig 3

Fig 3

Fig 1



L



Fig 4

Fig 1



Fig 2



Fig 3



Fig 4

h

Fig 5



Fig 6

a
e
t
d
d

a *b*

cl *r* *d*

e
p
d

h

Fig 7

a

t

ac

d
t

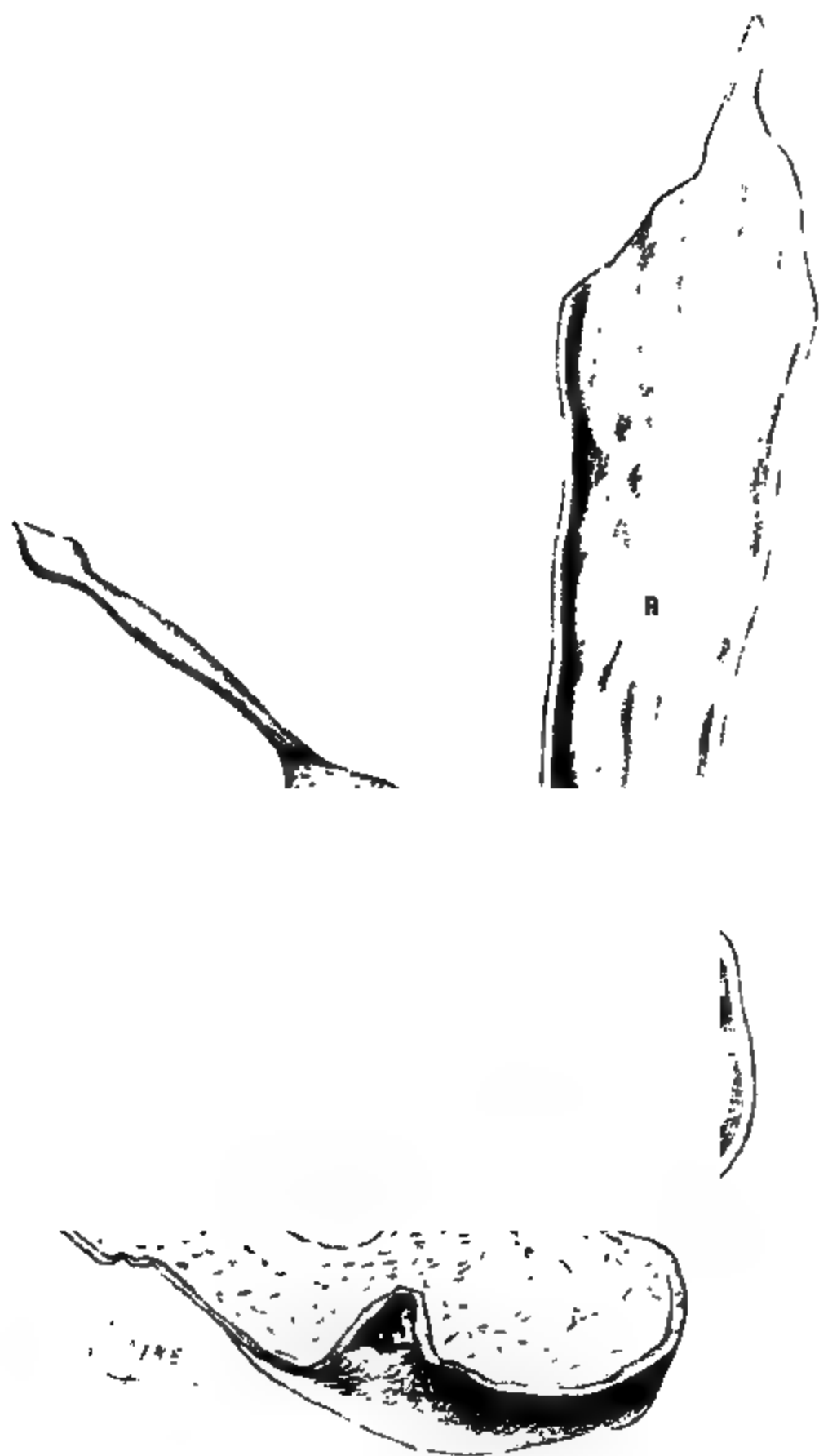
t
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h

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e

p



R, Rectum ; B, Bladder ; P, Prostate ; X, Union of Rectum with Urethra.

Journal of Anatomy and Physiology.

TERMINAL FORMS OF LIFE. By Professor JOHN CLELAND, M.D., LL.D., F.R.S., *Professor of Anatomy, University of Glasgow.*

(A Lecture delivered in St Andrew's Hall, Glasgow.)

[*Note.*—Although the following lecture was prepared for a popular audience, and the facts with which it deals are not new, I venture to publish it in a scientific journal, because the doctrine founded on the facts is one of scientific importance. I have not thought it advisable to change the style or omit explanations which were introduced for the benefit of persons not biologists, as it would have been difficult to have done so without damage to the argument. But I am not without hope that at a future time I may be able to put forward some more solid work bearing on the manner in which the advance of life has actually been effected.]

When the student of nature first surveys the animal kingdom, he is naturally struck with the immense diversity of living forms which it presents. Even if he confine his glance to a limited number of animals, and compare, for example, the extreme groups of vertebrates,—the mammals and the fishes, a dog and a salmon,—their dissimilarity will strike him first, in all probability; but as he observes more attentively, he will be surprised to find more and more of an underlying unity in details of their structure which in mere contour are very different in appearance. It is not a self-evident fact that the lateral fins of a fish correspond with the fore and hinder legs of a dog, yet they do so to such an extent that science not only admits the correspondence, but demands an explicit statement of the correspondences of

their various parts. All scientific men accept the justice of the inquiry, although their views are diverse when they attempt to work it out.

Parts thus structurally correspondent in different animals are called homologous. So, also, there exist in any one animal parts repeating one another in series, or on the right and left side, and these may be termed serially or symmetrically homologous. It is no new idea that in animals, the farthest removed one from the other, a certain fundamental correspondence or homology can be traced between their structures; and this idea, first grasped in its greatness by the immortal Oken, was exemplified in many points of detail by the great Geoffroy St Hilaire, the rival of Cuvier, and termed by him the "unity of organisation." It is an idea now much more generally recognised as having truth in it than it was formerly; but the men whom I have named, especially Oken, held it along with a conception of a higher unity than is grasped by the leaders of the biological fashions of the present day. Further, the study of development teaches us that the beginnings of all complex animals have a very similar origin in the egg, and in the first changes which the egg undergoes. An examination, moreover, of the stages of later growth betrays in numerous instances affinities between creatures which in their adult condition are altogether unlike. Thus, the barnacles that cluster round the keels of ships, and those others which encrust the rocks by the shore, degenerate though they be, are undeniable though poor relations of the lobster and the shrimp. More inanimate than the barnacles are those sacs, called ascidians, growing among the roots of sea-weeds, and dwarf kindred of theirs arranged in stems and leaves like zoophytes; yet these are found by development to be beyond contradiction related to vertebrate animals, though the details of the relationship are by no means certain. Perhaps you may form a still more vivid notion of the relationships laid bare by development when I tell you that the circles of blood-vessels round the throat, with slits between them, the arches from which the gills of fishes grow, are found not only in fishes but in the early condition of every animal from fishes up to man.

Then there is another line of research closely allied to development, namely, the study of the textures, which adds im-

portant witness to the unity of organisation; for it is admitted that the simplest elements of texture are bodies of the same description as the simplest kinds of separate living beings; and, in point of fact, the body of man is neither more nor less than an extremely complex and highly organised colony of these units of life, or living corpuscles.

Again, if, in addition to surveying adult animals and prying into their history from the egg, we look at the order in which animal forms have appeared on the scene in the long history of the fossiliferous crust of the globe, we shall find that, at least in the case of the vertebrate series, there has been a gradual sequence, beginning with the lowest and proceeding up to man. Among animals lower than these, the highest were also the latest to appear; and although types of all sorts, up to the nautilus, are found in very early rocks, it is curious to note, within the limits of different great groups, the simpler in various instances preceding the more complex.

Surely these investigations of organs, textures, development, and date of first appearance all combine to display animal life as a connected and progressive whole. They do not and cannot actually prove a common ancestry, though certainly they suggest the raising of the question, and the more that observation bridges the gaps between groups far apart, the more possible such community of ancestry will appear. But I do not suppose that any one denies that there is a line of main advance of life, of which we may look forward to being able to indicate the course more and more explicitly in detail, from the simplest beginnings up to man, nor that other lines diverge in different ways from different parts of that one stem.

But if, as many biologists do, we stretch our imaginations, and suppose that this stem and these branches are not only derived from a common stock, but are so derived mainly through the transmission to posterity of accumulated chance variations, which each on their first appearance proved serviceable to their possessors, then it may be argued with a show of reason that all the lines of development of forms will necessarily be indefinite, that in them all, change, progressive as well as other, will be occurring at the present time, very slowly, but as much as it ever did, and that it must continue to occur.

Now that is a view of life which I can by no means accede to, and do not hesitate to consider contrary to all evidence. I propose, therefore, to-night to show that the animal kingdom is full of forms which once reached, whether through uninterrupted lines of descent from a common ancestry or not, have no power to advance to a higher level. These are what I allude to in the title of this lecture as *terminal forms*.

But I must first explain, in an elementary way, the early stages in the main line of advance of animal life. We pass from masses indeterminate and spheroidal in shape, minute beings moving in water, barely visible or seen only with the microscope, mere isolated living corpuscles, beings scarcely if at all exhibiting separate organs, to others more elongated, with the mouth towards one extremity, which, in the event of the animal being fixed like a plant, is the extremity standing out free in the water, and, in the event of its moving about, is placed foremost, so as to come in contact with food as it moves along. Then, in such an animal, when not fixed but moving from place to place, there is one surface turned toward the ground and another toward the light, and having therefore very different relations. Thus, you observe that in the mere surroundings of animals of the simplest kinds there is a rationale and an excitant to be found for the origin, first of starry or cylindrical symmetry out of the original egg shape, then for the origin of a head and a tail end, and subsequently of a ventral and a dorsal aspect, with, as a consequence, so long as the growth is equal, bilateral symmetry, or a right and a left side. I may add that any advantage of one side over the other in growth would turn the body to one side, and, by being continued, originate a spiral, a form which abounds in the animal kingdom. Another series of complications sets in connected with the relation of different parts to the surface. The superficial part coming into relation with the world around becomes what Bichât called the *animal sphere*, devoted to sensation and locomotion; while the deep part round the digestive cavity becomes separated as the *vegetal sphere*, and the body cavity makes its appearance between.

As the axis of the animal further elongates, we next find the phenomenon called *segmentation* developing, that is to say, a repetition of similar parts in linear series, producing the sort of

arrangement with which every one is to some extent familiar in a centiped. In this segmentation I have latterly learned to recognise a mere modification of that process of complete division by means of which the simpler organisms multiply,—a process in which a whole individual breaks up into parts, and each portion receives the potentialities previously inherent in the individual parent mass. Such segmentation as this is not only found in all the groups which have ringed bodies, or have their limbs arranged in pairs, but is the mode in which the bones, muscles, and nerves, in fact the animal sphere of vertebrates up to man, make their first appearance. On this subject, however, I must not dilate. Much interesting work has been done, as well as speculation advanced, on the relation of the vertebrate to invertebrate animals, but it cannot be touched on to-night.

We are now in a position to proceed to the consideration of some of the instances of terminal forms among animals, and may begin with a few examples among invertebrates.

The first group to which I shall allude is the *lampshells*, so called from a vague resemblance to a Roman lamp, and termed Brachiopoda by naturalists. They are enclosed within a shell consisting of two valves, between which they may be described as vertically compressed, with generally a long spirally coiled arm on each side of the mouth. Forming a group of most marked characters, they stand far separate from all others, but their fundamental connection with the main line of life is at the level of the annelids or ringed worms. This is made clear by their development, though it might otherwise be difficult to trace. It will probably appear plain to you by comparing a view of a larval lampshell animal with the larva of the sandworm. The eyes, the circle of cilia, and a succession of segments are matters common to both. Now, what is the history of this remarkable form of life in the different ages of the earth? Why, one of the oldest fossiliferous rocks takes its name from a genus of lampshells, and is called the Lingula Flags, and yet the genus Lingula continues to exist at the present time. By whatever means the Lingula arose—with whatever ancestry—it had completed its development in those far-off days, long before the earliest trace of a vertebrate; and, after having completed its development, there it has remained, closing its valves through the long ages.

against all the changes of the outer world in that tremendous lapse of years which separates the deposit of the *Lingula* Flags from our own day. Surely to such a persistent genus as this we may fairly give the title of a terminal form. No doubt there is a limited degree of variation among these lampshells, and the *Lingula* may be said to be among the simpler kinds. But already in Palæozoic times we have the more complex also,—the *Spirifers* with their immensely developed arms, the *Productus* with complications of its own; and more than that, so early as the Old Red Sandstone, before the first trace of an amphibian making its appearance, the maximum number of different kinds of lampshells already exist, and since that time so ineffective have their accidental variations been in the struggle for existence that by far the greater number have become extinct, while they have left no other kind of animal behind that by any possibility could be supposed to have had them among its ancestors.

The ordinary bivalves—the group to which the cockles, oysters, mussels, and scallops belong—are another set of animals placed between two shells, but lying sideways between them, and very different from the lampshells, as well as from all other forms of life, while among themselves they have all fundamentally similar structures; and though it is true that they vary in habit as well as form, some of them resting in one place, while others leap, and others bore in mud, in wood, and in stone, they seem to be all very much on a level as regards advance or degradation. They are cut off by a wide gap from all other forms, and only in the embryonic condition is it possible to observe a resemblance, as in the case of the lampshells, to certain annelid embryos. They are a remarkably numerous group, and differ from the lampshells in having been able to hold their own in the struggle for existence to such an extent as to attain their maximum development at the present day. They have flourished from far-off Palæozoic times, and palæontologists describe from the Silurian rocks numerous species resembling pearl oysters, cockles, and mussels. There is no reason to imagine that any of them have become ancestors during all the time since then of animals other than bivalves.

It is just the same story which has to be told of that great group of animals known as Echinodermata, to which the star-

fishes and sea-urchins belong. They have so diverged from the main line of advance of life, that they have a structure so far asunder from all other animals that it could not be guessed by studying the adult condition. Both star-fishes and sea-urchins have had parts of the most remarkable and complex description, and you might have expected to find fossil remains leading up to them. I am not aware of any such thing, and whatever the characters of their predecessors, they themselves had already perfected their characters so long ago as when the Upper Silurian and Old Red Sandstone strata were deposited; and through the ages since then, including by far the greater part of the epochs of life known to geologists, they have continued to persist, and they are as much as ever star-fishes and sea-urchins even now. These also, by the stages through which they pass in their larval history, are indubitably connected with the annelids; and indeed an examination of embryonic forms seems to bring out a very curious relationship of echinoderms and bivalves, for in bivalves the preoral part, constituting the velum, dwindles and disappears, while in the embryo of the feather-star or antodon it was pointed out by the late Sir Wyville Thomson that the permanent animal was developed altogether in the preoral part.

I would only allude to one other highly divergent group of invertebrates—that to which the nautilus and the cuttle fishes belong—universally acknowledged to be the most highly organised of invertebrate animals, and perhaps the most intelligent, but situated far away from all possible connection between the invertebrates and the vertebrates. Notwithstanding the high complexity of these animals compared with other invertebrates, their ancestors have not been occupied by any means up to the present time fighting their way up to that position, and so left us to believe that the present forms may in time become in turn the ancestors of creatures wholly different. On the contrary, allies of the nautilus are recognised in the Silurian rocks, while mummied remains of an extinct description of cuttle fishes called *Belemnites* declare that at a time considerably before the chalk cliffs of England had begun to be deposited at the bottom of a long bygone sea, the remarkable anatomy of the cuttle fish was already exemplified in a completeness which has indeed been varied, but not essentially deviated from since. The

nautilus and the cuttle fish are thus both of them terminal forms.

Not nearly so divergent from the main line of advance as any of the forms of which I have spoken are such animals as Crustaceans and insects; but it is worthy of notice that, however vaguely understood the line of advance may be, it seems perfectly certain that it was from no modification of such animals with jointed limbs that vertebrate animals arose.

We come now to the vertebrates themselves, and these, as you are aware, were arranged by Cuvier in four series from below upwards, viz., fishes, reptiles, birds, and mammals; but the fishes and reptiles exhibit among themselves a variety such as is not at all approached either among the birds or the mammals. The fishes are bound, after a fashion, in one group, by the fact that the heart propels the blood by one main vessel in a single circulation through the gills and on into the rest of the body, without directly giving off special vessels for the supply of lungs; but the reptiles show four entirely separate divisions, the highest of which contains the lizards and crocodiles, while another includes the turtles, a third the serpents, and a fourth the newts and frogs. This last group, most usually termed now-a-days the Amphibia, is on a lower level than the other three, and more nearly allied to the fishes; so much so, indeed, that rightly or wrongly the majority of naturalists at present separate them from the reptiles altogether, and look on them as a distinct class.

The fishes which at the present day make the nearest approach to the Amphibia are a few species from Africa, America, and Australia, termed the mud fishes. It may be about fifty years since the first of them was discovered, and it was actually taken by some naturalists for an amphibian. The limbs are reduced to pointed oars, without, however, the division into a limited number of terminal toes, characteristic of the limbs of animals higher than fishes; and the structure which you are familiar with as the swimming bladder of fishes has become exactly similar to a pair of lungs such as those of the frog or the serpent, both in structure and function, receiving blood which is vitiated and sending it back pure; but notwithstanding all their resemblance to amphibians, their internal peculiarities, especially those of

the intestine, are of such a description that no actual transition could ever have taken place from them, or animals near them, to amphibians. They are, in fact, now-a-days correctly recognised as closely allied to the Ganoids, a group occurring abundantly in very ancient strata, and characterised by a covering of plate armour, which the mud fishes have not got. The Ganoids and the cartilaginous fishes (Elasmobranchs), of which the sharks¹ are a familiar example, are the most ancient fishes known. The Amphibia are also of extremely ancient origin, though, so far as we know, not so old as the cartilaginous and plate-armoured fishes; and they are certainly much older than the bony fishes, the ordinary typical fishes of the present day. Thus you will see that, if there is blood-relationship between the fishes and the frogs, we must look for the parents of the frogs in days as far back as those which have sent down to us no relics save of ganoid and cartilaginous fishes. They had in all probability skeletons at least as perishable as the cartilaginous fishes; and, as the amphibians have naked skins, they would probably be destitute of ganoid armour, while, on the other hand, like the Ganoids, they must have had the first appearance of lungs in the form of a swimming bladder opening into the gullet. Such animals may easily have existed and left no trace behind.

Now, what is the position of the ordinary bony fishes, which are at present by far the most abundant of all, while the Ganoids have become very few in number, and the sharks and their allies present a not very great variety of genera? The bony fishes are much further off from the main line of advance of life. They make their first appearance long posterior to the sharks and Ganoids, and we know nothing of their original connection with the line of advance. They have the most curious visceral arrangements, different from all other animals, and mostly presenting a simpler appearance than those obtaining in any other vertebrates; so that, if it were not for the evidence of geology and development, one might have thought that the bony fishes

¹ The very imperfect nature of most of the remains of fossil sharks gives great importance to such specimens as that described by Dr Traquair (*Geol. Mag.*, Jan. 1884) in which the configuration, soft parts, and integument are sufficiently preserved to demonstrate the affinity to modern species.

must have come first, especially as the sharks have a very distinctly higher development of brain. They have made good use of their time in the world to branch out into all manner of the most extraordinary eccentricities of outward form, and yet have remained wonderfully true to a common type in all the fundamentals of internal structure. The mechanism of their heads is specially worthy of notice. In the sharks there is almost always found a curious arrangement, in which the bones of the face are suspended from the skull by just one point on each side opposite the ear, an arrangement which is simply the continuance, in the skeleton in adult life, of a condition which the young of every vertebrate passes through at an early period, so that a shark may be said to have merely an arrested development of the face bones. But among the Ganoids we find all sorts of transitions between the shark-like skull and the arrangement in bony fishes; and in the bony fishes, while the face bones agree so far with the higher vertebrates that they are connected with the skull right forward to the front, the details of all the bones are quite different from anything found in the higher vertebrates; and, in addition, there is a complicated and elaborate gill-cover, represented in all higher animals by so minute a rudiment as not to be generally recognised.¹ Also the limbs of fishes, *i.e.*, their pectoral and ventral fins, take on in the bony group most fully and constantly a special complex mode of development peculiar to fishes, evolved from embryonic rudiments similar to those from which the limbs of other vertebrates take origin, but so different from them that anatomists by no means agree in determining the details of the correspondence. And in position as well as structure they are peculiar; for in almost all the bony fishes the fore-limb is attached to the head, which it has no connection with in higher animals; and in some, such as the cod

¹ The allusion here is to views which the writer has not had time hitherto to publish. He recognises in the operculum the stapes, and is supported in this belief by the observations of Parker and of Fraser, from which he gathers that the stapes is a radiation from the suspensorium or incus. The suspensorium and lower jaw he continues to hold to be an arch not belonging to a single segment of the skull, but related to it as the pelvic and shoulder girdles are related to the vertebral column.—Parker in *Nature*, xxvi. p. 252; Fraser, *Phil. Trans.*, 1882, p. 901; Cleland, "Interpretation of the Limbs and Lower Jaw," *Brit. Assoc. Rep.*, 1869, Trans. Sect., p. 119.

family, the ventral fins also are drawn forwards, and hung from the shoulder girdle.

Probably I have said enough to make good the position that bony fishes are a divergent group, with no tendency to rise in the scale of being. They have achieved a development of their own, beyond which they show no symptom of passing in the present, any more than during long geological ages the lamp-shells, the common bivalves, the star-fishes, or the sea-urchins have shown disposition—any of them—to transgress the narrow limits of the plan on which each of them is founded. I go further, for, as I conceive of the vertebrate division of animals, those fishes with the ventral fins brought forward under the shoulders express a developed idea of fish-hood more fully than any others; they are, namely, animals in which brain and spinal cord are dominant, having the viscera and limbs crowded up under the head, while the greater bulk of the body is mere spinal cord with the skeleton, muscles, and integument belonging thereto. But as soon as we leave the fishes we find the body dividing into three great regions—belly, breast, and head; and the reptiles, birds, and mammals are groups in which each of these regions respectively has a dominant development.

Reptiles, birds, and mammals are acknowledged by all to form an ascending series. Birds have not only the advantage over reptiles of being warm-blooded, which means that they present a vast increase in all their activities, but they have very differently developed brains, and have the circulation which takes the vitiated blood to the lungs thoroughly distinct from that which takes the aerated blood to the tissues. Then mammals, while they present in the circulatory system only a difference from birds, not an advance beyond them, have much more highly developed brains than they, and within their own limits exhibit the most extraordinary additional advances in brain structure, which culminate at last in man. But while we have thus placed before us a gradually advancing chain of animal forms, consisting of fishes, amphibians, reptiles, birds, and mammals, and these different kinds of animals have appeared, according to the geological record, strictly in the order named, so that they constitute beyond all question an evolution of the idea of animality on the face of the earth; yet it is not along this chain that we can pass

in tracing a possible line of ancestry of birds and mammals. Among extinct animals there are various which seem to bridge to a considerable extent the gap between amphibians and lizards, as Owen has pointed out; but it seems difficult to bridge the gulfs between the lizards, the turtles, and the serpents, without going back again to the fossil amphibians. Then it is palpable that the gulf is still greater between birds and reptiles, even when we take into account the peculiarities of that remarkable fossil bird, the *Archæopteryx*, which, besides having apparently had teeth, as some other fossil birds had much more distinctly, had a tail with a long chain of vertebræ in it, and claws on one or two digits of its largely developed wing-bearing arm.

There are indeed various forms of fossil reptiles which invite comparison in some respects with birds. Thus the *Iguanodon*, whose giant skeleton may be now seen adorning the court of the Museum at Brussels, makes in a few points a most interesting approach to birds. The evidence appears to show that it was a biped; it has ossified tendons, like what you are familiar with as occurring in birds, and has in its hinder or lower limbs some distinct anatomical approximation to bird peculiarities; but it has the head and arms of a lizard, and these are not at all similar to the head and arms of birds. For reasons such as these, I suspect that if we are to seek for an ancestral origin of birds from lower forms we must go back again as far as the ancient fossil amphibians.

Then, as regards the origin of mammals, they differ immensely from birds in every osteological detail, in integument, and in ovum; while every known form of reptile shows some sets of peculiarities which distinctly announce that it cannot be regarded as a mammalian ancestor. Even Professor Huxley has stated his opinion "that the Mammalia have been connected with the Amphibia by some unknown 'pro-mammalian' group" (*Proc. Roy. Soc.*, xxviii. p. 404). Therefore I am not singular in denying their descent from birds or reptiles. You will notice, however, that this common descent of all vertebrates is a mere hypothesis, one which, for reasons founded on analogy, I own to regarding in some of its conceivable forms with favour; but a hypothesis surrounded, as you cannot fail to see, with enormous difficulties, difficulties which, with all respect for the opinions of those who

teach otherwise, I must declare to be fatal to the notion that the ascent has been accomplished by natural selection.

The reptiles of the present day, and all birds, may without hesitation be put down as divergent from the main line of advance of life. Are they indefinitely divergent? or do they present terminal forms? Birds are so definite in their structure; within the limits of their narrow variation they display such numbers of different kinds, and they have persisted so long true to their own peculiarities of structure, that we may well judge them to be a terminal group, showing no capability of passing beyond the limits of their special characters, and certainly no tendency to rise above them.

For illustration, both of the divergence of bird structure from the main line of advance and of its persistence within very narrow limits, we may look at the skeleton of the wing. For some mysterious reason, which I do not pretend to understand, the number five governs the number of digits in both limbs from amphibians upwards. But the wing of the bird, modified to become the support of the large feathers which stretch outwards and backwards from it to beat the air, has the part corresponding with the hand of man or the fore-foot of other animals so shorn of the parts seen both in reptiles and mammals that its middle finger is the only one which has so many as two or three joints, while its ring finger has but one; its fore-finger is represented by a vestige of the bone which should have supported it, and the thumb and little finger have disappeared altogether. Such is the skeleton of the wing found generally in the numerous families of birds, though more or less dwindled in the ostrich and its allies. The history of its first appearance in the world is not known, but its persistence without essential modification in such an enormous number of species is a very remarkable circumstance.

Very different it is from the wing of the extinct pterodactyles, small reptiles which came nearer in various respects to birds than did the Iguanodon, and were eminently adapted for flight. But they had the hand or fore-foot well developed with four digits bearing claws, while the fifth, corresponding to our little fingers, were so enormously developed as to be as long as the backbone, and served for the stretching of wings of a mem-

branous kind, like those of the bat. The pterodactyle wings are not approached by any preceding animals known to us; and their possessors, supposed according to the fashionable theory to have obtained them in consequence of the advantage that their gradual development to such a size gave them in the struggle for existence, seem to have made a very bad fight indeed with the fates, for they were not continued in any modified form.

There is a third arrangement by which vertebrate animals have been made to fly. Among mammals, the bats have mastered the art to perfection. In this instance the wing is made on a quite different plan, being spread upon four fingers, all of them enormously developed. But neither in this instance have we any acquaintance with stages leading up in the part to this form of wing, nor have we among animals of the present day any intermediate forms to bridge the gap between those organs of flight and paws used for walking and seizing.

Just as the wing of the bat is an extreme modification which it would be difficult to imagine further exaggerated with advantage to flight, and puts the possessor to one side off the main line of advance of life, so also the limbs of the horse declare that genus to be a terminal form. A horse moves on the tips of the nails of its middle fingers and toes; and the construction which enables it to do so is reached by colossal enlargement of these digits, while the others disappear. The horses of the present day were preceded by animals which had a more distinct second and fourth toe placed on the sides of the third; while these again were preceded by others with three toes all reaching the ground; and you can pass back from that to animals with five toes.

But it is interesting to note that the horse is not the only terminus among mammals, reached, so far as the limbs are concerned, by disappearance of some toes and exaggeration of others. There are animals with the thumbs absent, and with the third and fourth toe big, while the second and fifth are small, as in the pig, or still further dwarfed as in the chevrotains; while in the deer the second and fifth toes hang loose without bones to support them, and in the ox and sheep only two toes are left on each limb, the second and fifth being obliterated from the skeleton altogether. In the ruminants, as well as in the horse, the exaggeration of certain digits has taken place side by side with the

dwarfing of others ; and it does seem exceedingly improbable that any advantage could accrue to either horse or cow by the further exaggeration of its developed digits. I submit it, therefore, as reasonable to consider theirs as the limbs of terminal forms.

Let us examine now, very shortly, what the position of man is. There is no possibility of doubting that the animals most nearly approaching him are the apes, and that among these the orang and the gorilla are the highest. So far as the skull is concerned, the orang is decidedly nearer to the human form than the gorilla. Different naturalists hold different opinions as to the importance of the gap between the structure of these animals and the human body ; but there can be no doubt of this, that they lie nearly in the line between monkeys and men. They are not divergent ; on the contrary, the arboreal peculiarities of the monkeys are less extreme in them. Neither are they termini of form. But man is a terminus, and not only *a* terminus, but *the* terminus of the advance of vertebrate life. That may seem a proposition hard to prove, since we have no telescopes to bring the future near. But look at the whole history of the advance of life from the simplest animals up to man. What has it been but the growth of structure fitted for the exhibition of consciousness ? Thus the eye passes along one line till it reaches the higher insects, with a perfection of movement and special sense very remarkable, and a kind of intelligence which baffles us to comprehend either in its physiological or psychical relations, and there the line stops. Another line leads us to the cuttle fishes with their splendid eyes and arms and swiftness as compared with other molluscs, and we can trace that line no further. We come to the vertebrates. We ascend through its groups to the mammals, all of which exhibit a sagacity, as distinguished from instinct, superior to what is met with in any other animals ; and among the mammals there are some which have maintained their place in the struggle for life by acuteness of sense, some by cunning, some by ingenuity, some by protective armour, some by weapons of offence, and some by swiftness of foot. To cold and heat, to mountain and plain, to cave, to marsh, to forest, to water, you meet with diverse adaptations. But that which is universally recognised as ascent in the scale of being is always intelligence, and man is the one animal the whole struc-

ture of whose body is subordinated to mind. On reaching man the idea which runs through all the animal kingdom receives its full expression, and those modifications of vertebrate structure by which this is achieved are of such a description that they cannot be carried further.

In stating that in the construction of man full expression is given to the idea running through the animal kingdom, I mean that while the rise of organisation has always been associated with the development of intelligence, and the vertebrata, with their great nervous system symbolically placed superiorly, exhibit this in a special manner, in man a construction is reached which is calculated and intended to be the instrument of thought. It is in connection with this that in man the upright posture is reached for the first time. Man is the only animal who is maintained by balance in the upright posture and supported on straightened knees. The arch of the instep is peculiar to him, and the whole lower limb is modified, and also the trunk; while the head is adapted to the balanced position by changes necessitated in its proportions as containing the developed organ of thought, the brain, and bearing the face modified as the special organ of the expression of thought. By the elevation into the upright posture the symbolism in the position of the great nervous centre is carried a step further, the brain assuming the uppermost place, while the shortened spinal cord is thrown behind. More important, perhaps, in the eyes of matter-of-fact persons is the circumstance that the proportions of the parts of the brain are totally different in man from those of the brains of the highest apes, there being an enormous development of the hemispheres or portion of the brain specially connected with thought, leaving a gap between the apes and the lowest human brain much greater than between the lower and higher races of men—a gap, moreover, altogether unbridged—while the differences of human brains are graduated so that there is no link wanting. But, further, the development of the brain is in connection with a whole system of development of the head and face which cannot be carried further than in man. For the mode in which the cranial cavity is gradually increased in size is a regular one, which may be explained thus: we may look on the skull as an irregular cylinder, and at the

same time that it is expanded by increase of height and width it also undergoes a curvature or bending on itself, so that the base is crumpled together while the roof is elongated. This curving has gone on in man till the fore end of the cylinder, the part on which the brain rests above the nose, is nearly parallel to the aperture of communication of the skull with the spinal canal, i.e., the cranium has a curve of 180° , or a few degrees more or less. This curving of the base of the skull involves change in position of the face bones also, and could not go on to a further extent without cutting off the nasal cavity from the throat. The projection of the muzzle, which has hitherto occurred in connection with jaws for seizing hold of food, disappears, only a vestige remaining in savages; and there would be neither beauty nor functional advantage in any further retreat of the face under the skull than is represented in classic statuary. Thus, you see, there is anatomical evidence that the development of the vertebrate form has reached its limit by completion in man.

I need scarcely enlarge on what has so often been pointed out before, how in man intelligence operating through the brain, and served by a hand perfected in its proportions for the conduct of fine manipulations, makes up for want of protective covering, for want of natural weapons of offence, and even for want of keenness of the senses,—so that in the history of man progression passes away from the modifications of bodily structure to the evolving progress of man's many inventions, and the whole history of human thought, with its heavenward ascent and its abysses of degeneration.

But so far as the structure of the human frame is concerned, the differences between the highest and the lowest races of men are not of such a description as to warrant the supposition that they are capable of indefinite increase either in the direction of degeneration or progression. The superiority of the higher races is principally marked by the abolition of all muzzle-like projection of the teeth, the development of a prominent chin, a slightly increased curvature of the cranium, considerable increase of the cranial cavity, and a more highly convoluted surface of the brain. The absence of muzzle and the presence of chin are mere ornamental peculiarities. The superior organisation and dimensions

of the brain are granted to be valuable, and to indicate some sort of difference in mental power; but take care that you are not led away into supposing that there are unlimited possibilities of human progress to be found in cerebral expansion. Remember that the brain is only part of a limited organism on which it depends for nourishment, and for which in turn it is obliged to have consideration. Remember also that there are limits of time. The time spent in lucubration is lost for action, and that which is occupied in one sort of education is lost for others. The living parts of all living bodies have so much in common that scientists of the day call them all by the name of protoplasm; as they all do their work by similar processes of chemical change, it is plain that there never can be a brain that can work in any other way. It follows that the heavier the brain the more expensive it is to work it; and it may be added that the heavier the brain, probably the more difficult is it to get it to work all at once in harmony, and with the mental energy which it permits all concentrated on one object; and this perhaps may partly explain how so much brilliant work is done by very small brains, and often none at all by big. Altogether, it seems in the last degree improbable that in the future there will be a progression in the construction of the human body that will give birth to greater intelligences than the sages and heroes of antiquity.

To me the animal kingdom appears not an indefinite growth like a tree, but a temple with many minarets, none of them capable of being prolonged,—while the central dome is completed by the structure of man. The development of the animal kingdom is the development of intelligence chained to matter; the animals in which the nervous system has reached the greatest perfection are the vertebrates; and in man that part of the nervous system which is the organ of intelligence reaches, as I have sought to show, the highest development possible to a vertebrate animal, while intelligence itself has grown to reflection and volition. On these grounds, I believe, not that man is the highest possible intelligence, but that the human body is the highest form of animal life possible, subject to the conditions of matter on the surface of the globe, and that its structure completes the design of the animal kingdom.

OBSERVATIONS ON RICKETS, &c., IN WILD ANIMALS.

By J. B. SUTTON, F.R.C.S., *Senior Demonstrator of Anatomy, Middlesex Hospital.* (PLATE XVIII.)

INTRODUCTION.

IN the year 1650 a small book was published in London, entitled "*A Treatise of the Rickets: Being a disease Common to Children. Published in Latin by Francis Glisson, George Bate, and Ahasuerus Regmorter, Doctors in Physick and Fellows of the Colledg. of Physitians at London.*"

This was the first systematic account of a disease which, in its usual form, does not require any skill to recognise, and is unfortunately so common that an ordinary schoolboy is familiar with the term, the name, "rickets," being a byword.

Since the date of Glisson's book (which passed into a third edition), rickets has been ably investigated clinically, pathologically, and experimentally by very many observers up to the present time, and a long list of monographs, dissertations, lectures, and papers by distinguished authors has been devoted to the elucidation of its pathology and the best means of treatment. Therefore, it seems a little strange more attention has not been devoted to this malady in animals. That domestic animals and wild beasts in captivity suffer from rickets was certainly known, is attested by the fact that the Museum of the Royal College of Surgeons, London, possesses specimens exemplifying the condition of the skeleton affected by rickets, as it occurs in lions, cats, and monkeys, several of the preparations being marked "Hunterian." The *Proceedings of the Zoological Society*, for 1845, contain a paper by Professor Percy, in which is mentioned the death of certain monkeys from an affection of the skeleton resembling *mollities ossium*.

Otto, writing in 1830, states that rickets usually occurs in the early period of youth in man and animals. He had observed it in puppies, calves, lambs, and young monkeys. Examples are given by Sandifort (*Mus. Anat.*, vol. iii.), from the monkey, dog, and porcupine.

Later on Otto speaks also of *brittleness* of bone, a diminished consistence, which may occur in early youth, but generally only in advanced age; it also occurs in animals, he having noticed a great degree of brittleness in several monkeys, in a hyæna, in a two-year old lioness, in some dogs, stags, and roes.

This same writer speaks of a softening of bone which occurs in adults and old people; this is especially called *osteomalacia*, *rachitis adultorum* and *senilis*. It is much more common in the female than in the male sex. It was found in the horse, ox, sheep, dog, cat, rat, in very many monkeys, and one polar bear. In the birds the disease appears to be more rare.

In the debate on rickets at the Pathological Society, in the session of 1881, Dr Crisp mentions the occurrence of the affection in birds, wild and domesticated animals.

Dr Murie, who formerly held the appointment of prosector to the Zoological Society, was aware that many of the animals dissected by him exhibited marked rickety changes in the bones; but that rickets was as common, or even more frequent, among wild animals in captivity than among children, was never in the least suspected; indeed, so far as can be learned, no one had investigated the subject with the care and attention it deserved.

Some three years ago the author of this paper was appointed (as one of the Committee of Comparative Pathology) to make *post-mortem* examinations upon the animals dying in the Zoological Gardens in Regent's Park, and to show at the Pathological Society such specimens which came to hand of pathological interest. The result has been, that during the sessions of 1882, 1883, and 1884 several papers have been contributed on the subject of rickets in wild animals, which go to show that it is an affection of astonishing frequency, and a very common cause of death among wild animals in the captive state. Many opportunities, and so much material, have come under notice as to enable a fairly complete and comprehensive description to be written of this singular disease as it occurs in animals.

Before proceeding to discuss the subject in detail, it will be well to give an account of some of the difficulties which arose in the early part of the investigation. The first specimens shown at the Pathological Society, and described in the *Transactions* for

1883, were from monkeys, the great defect in the communications being the inability to ascribe any definite age to the patients. All this uncertainty depended on the fact that the *Quadrumana* rarely reproduce in the gardens; if they do bring forth young, the offspring rarely survive; and so little reliable information as to the age of the monkeys was forthcoming, even from those who were in a position the most likely to afford evidence on this point, that for a time the inquiry was much hindered.

Finding it almost impossible to satisfactorily settle the question within reasonable time, attention was directed to another group of animals which do occasionally breed in confinement and whose young survive. The smaller Carnivora have fulfilled the required conditions, and reliable indications may be given to determine certain curious and interesting features in the course of the disease, which, for a time, were somewhat obscure.

A mammal from birth to maturity passes through an intermediate stage, viz., that of puberty, and we have in consequence three very definite periods,—1, infancy; 2, puberty; 3, maturity. In animals the stage of infancy corresponds to the development of the chief secondary centres of the long bones, such as the condyles of the femora, the heads of the tibiæ and humeri, the extremities of the radii, ulnæ, &c.

As infancy yields to puberty, the terminal caps of cartilage belonging to the limb bones, although separated from their shafts by the thin epiphysial cartilages, are nevertheless thoroughly ossified, only the smaller insignificant epiphyses retain the cartilaginous condition. Now, changes are obvious in the vertebræ; the complementary centres for the processes and epiphysial plates of the centra make their appearance, and the spinal column becomes the seat of active change and growth. In infancy the *appendicular* skeleton is undergoing rapid changes, whereas at puberty the activity becomes transferred to the *axial* skeleton.

If an animal of uncertain age falls into one's hand, the age may be determined for pathological purposes by the following test:—

1. If no epiphysial lines be detected, either in the spine or

appendicular skeleton, the animal is thoroughly adult ; often degrees of maturity may be estimated by the condition of the cranial sutures.

2. If the complementary plates of the vertebræ remain distinct, the epiphyses of the long bones not fused with the shafts, and many of the smaller epiphysial centres only just appearing, the animal must be considered as in the period of puberty.
3. No secondary centres in vertebræ, and those in the long bones small, the animal must be regarded as an infant.

That some such rules as these are absolutely necessary to guide one, is illustrated by the facts that some animals attain puberty in a few months (certain rodents), while others require two years for the complete growth of the skeleton, and many larger animals several years. It has been stated that—knowing the age at which the lower epiphysis of the radius unites completely with the shaft, and multiply the time occupied by four—the result represents the average age of the animal.

The rule is only applicable within wide limits, nevertheless it is exceedingly useful as affording at least an approximate estimate of the duration of life for any particular animal. As the symptoms, pathological appearances, and distribution of the lesions vary with the age of the animal affected with rickets, it is necessary to divide the subject and describe the disease in three forms :—

(1) Rickets of infancy, (2) of puberty, and (3) of maturity.

Although typical cases belonging to each period will be described, nevertheless instances, as would reasonably be expected, occur at intermediate ages, in which the skeletons present conditions exactly midway between any two forms corresponding with the creature's age. As in matters of natural history, so in pathology. Nature is ever ready to break down the barriers of hard and fast systems of classification ; and though lines of demarcation are often essential to mark culminating points, at most they are always to be regarded as arbitrary arrangements.

RICKETS OF INFANCY.

Symptoms.—The clinical aspect of the disease has been chiefly followed out in monkeys. When one of these creatures becomes affected with rickets it is less lively than usual. Instead of leaping from bough to bough, fighting, or otherwise displaying evidence of agility, the monkey grovels about on the floor, and, if pushed, shrieks as though the movement caused pain. By degrees the power of locomotion becomes considerably impaired, the creature displaying signs of paralysis in the lower limbs, finally ending in paraplegia, accompanied with priapism, incontinence of urine, and fæces. The mode of progression is now characteristic. The hinder portion of the body being paralysed, the monkey is obliged to use the long fore limbs as crutches, and swing the trunk between them. At this stage deformity of the chest is obvious. A well-marked kyphotic curve of the spine is established in severe cases, and the creature presents a very pitiable condition. A sudden change in the weather, or exposure to a draught of cold air, sets up a slight attack of bronchitis, and as sure as a rickety monkey develops a cough, be it even a slight one, the animal soon succumbs. Such opportunities as have occurred for watching the course of the disease in other animals, *e.g.*, Carnivora and Rodentia, give similar effects.

The disease develops with remarkable rapidity. I have seen a Capuchin monkey in good health, and apparently thriving well, die horribly deformed, in consequence of rickets, four months after.

MORBID ANATOMY.—At the autopsy the most noticeable features are the deformity, particularly the kyphotic curve of the spine, which, in some cases is so pronounced that the symphysis pubis and xiphoid cartilage almost touch one another (Plate XVIII. fig. 1.)

The sinking in of the thorax in many cases is so great that the costal cartilages of opposite sides approach one another so as almost to come into apposition; indeed, this would often happen but for the heart being pushed forwards and occupying the interspace.

The chief visceral lesions are connected with the lungs, heart and liver, but only the lungs exhibit any constant lesions.

1. *Lungs*.—In nearly all cases of rickets occurring at the period of infancy, when the ribs are soft and yielding, the lungs present a condition of atelectasis; so extreme is the collapse in some cases that it is hard to imagine how the animals managed to breathe. In certain specimens broncho-pneumonia may be detected, and these two affections, complicating rickets together or separately, kill the majority of monkeys brought to this country.

2. *The Heart*.—As before explained the heart often gets compressed between the yielding thoracic parietes and pushed forward against the sternum. Thus in the movements of the chest walls during respiration, friction is set up between the two layers of the pericardium. The consequence of this attrition is, that a "milk-white patch" develops on that portion of the heart subjected to the rubbing, whether it be auricle or ventricle, and on one occasion the "patch" was situated on the superior vena cava.

3. All animals living in confinement for any considerable length of time become possessed of fatty livers, so that its occurrence in rickets does not excite surprise.

4. During the examination of more than two hundred rickety monkeys, only twice has the spleen been found enlarged; in these two instances it was about twice as large as usual, with a hard resisting feel and a thickened capsule.

5. In many cases the stomach is dilated, being often twice or thrice as large as in its normal condition.

6. *The Spinal Cord*.—In animals which have exhibited during life symptoms of paraplegia, the cord in the lumbar region is found to be compressed by a narrowing of the bony canal in which it lies. The cause of this will be explained fully later on. When the compressed cord is subjected to microscopical examination the most obvious changes are these:—

The nerve tubules near the periphery looks as though the medullary sheaths were removed, and in many places the axis cylinders are destroyed also; nearer the grey matter the axis cylinders may be detected; fatty granules are abundant; the grey matter contains few, in some places no nerve-cells, and such as remain are distorted and compressed; in fact, the structure of the cord is thoroughly disorganised.

The gross morbid anatomy of the skeleton will now be considered, commencing with the AXIAL SKELETON.

1. *The Thorax.*—The bony framework presents the well-known deformity “pigeon breast,” presenting in its details those features characteristic of the same condition, so familiar to all physicians, in young children, subjects of well-marked rickets. As before mentioned, in severe cases the yielding of the ribs takes place to such an extreme degree that the costal cartilages of opposite sides come almost into contact. It is this compression of the thorax by atmospheric pressure, hampering the lungs and causing them to collapse, that makes rickets such a formidable disease, so far as life is concerned.

Large beads form at the junctions of the rib-shafts with the costal cartilages, the enlargement being confined to the rib itself, and most obvious on the pleural aspect of the thorax.

Very often a double series of rickety beads may be found on each side, this second row being situated near the angles of the ribs. These adventitious swellings result from infractions, that is, the ribs are so bent in at the anterior portion of the chest that the ribs near the angles are fractured, but the periosteum remains intact, at least in the majority of the cases. The movement of the broken bones in respiration causes a large amount of thickening, due to provisional callus, leading to the bulgings in question. In the most exaggerated example of rickets which came under my notice, a Macaque monkey, seventy-six “infractions” were counted on the ribs alone.

In a few specimens of rickety monkeys the chest has exhibited a deformity in the opposite direction; instead of being laterally compressed, the sternum is bent upon itself at an obtuse angle, as though the xiphoid cartilage and the manubrium were endeavouring to meet. In these cases the lateral measurement is increased, the antero-posterior and vertical diameters are diminished. This is caused by the high degree of kyphotic curvature tending to make the symphysis pubis and costal arch approach one another, thus narrowing the space for the abdominal viscera; at the same time the stomach undergoes dilatation and pushes up the ensiform cartilage. The condition is peculiar to monkeys. Carnivora and Rodentia suffer, so far as I

have examined specimens, only from the lateral compressions, but they frequently exhibit "infractions" of the ribs.

The Skull.—Phenomena of interest and importance occur in this part of the skeleton. As a rule the bones are so soft that they may be cut with an ordinary knife, and repeatedly have I split the skull as easily as though it were made of gutta percha. The bones of the cranial vault are usually slightly thickened and spongy, often presenting a worm-eaten appearance on their exterior.

The bones forming the base of the skull undergo a peculiar process of thinning known as craniotabes. This condition most frequently attacks that part of the squamo-occipital bone which lies below the curved lines, and is of cartilage origin; in some instances the cerebellar fossæ on either side of the foramen magnum are so thin as to creak under the finger like parchment, and in certain instances actual perforations occur. Tabetic patches exist at times over the orbits.

The singular contrast of the effects of this disease on the skull cannot fail to arrest attention; bones of membranous origin thicken somewhat, whereas those preformed in cartilage show thinning. The teeth are, as a rule, normal in number and in size, but these structures will be more fully considered later on.

The Vertebral Column.—It has been known for several years that very many monkeys die paraplegic, but the cause of this symptom has never been fully worked out until recently. In addition to the kyphotic curve presented by the spine, the individual vertebræ become exceedingly soft, indeed so soft that in conducting *post-mortem* examinations, the bodies of the vertebræ may be cut through as easily as the intervening fibro-cartilaginous discs. Consequently, when the animal stands, the pressure of the superincumbent weight causes the softened vertebræ to yield and press upon the cord in its canal, and to injuriously compress the spinal nerves as they issue from the intervertebral foramina. In addition to the actual softening and bulging of the bones, a layer of ossific matter is deposited on the interior of the canal; this in its turn tends to narrow the usual ample space allowed for the cord and its membranes.

That the nerves do get squeezed may be illustrated in this manner. If a monkey just showing signs of paralysis be made to stand up, it shrieks in a frightful manner in consequence of

pain due to pressure, and when manipulated evidence of pain may be observed.

THE APPENDICULAR SKELETON.—1. *Upper Limb.*—The clavicle is usually thickened especially at the sternal end.

The scapula is soft and spongy, allowing the serratus magnus and subscapularis muscles to invert the posterior border.

The humerus, radius, and ulna soften, their shafts thicken and their epiphyses are often twice or thrice the normal size. The medullary cavity is large and filled with red, vascular medulla. The most distinctive signs are to be found at the epiphysial junctions, where, replacing the thin narrow streak of hyaline cartilage, a band of tissue is seen, frequently five, and in some cases ten, millimetres in thickness, the increased breadth being due to a substance named by Guérin spongioid tissue. The lower epiphysis of the radius and the head of the humerus are the seats of the greatest change in the upper limb. The carpal and metacarpal bones share in the general disturbance. The long bones, in addition to the changes above described, undergo abnormal curving in the direction of their length, but these softened bones rarely break.

The periosteum of the long bones is thick, succulent, and easily separable from the shaft.

2. *The Lower Limb.*—With the exception of the changes connected with the pelvis, the description of the upper limb would apply to the bones of the lower extremities, viz., thickened periosteum, curved shafts, enlarged epiphyses, irregular growing lines, softened texture, and increased vascularity. The changes are most obvious in the lower ends of the femur and tibia. The condyles of the femur I use as my test. If rickets be suspected, an examination of the lower epiphysis of the femur will either confirm or disprove the suspicion.

The pelvic changes are important on account of the narrowing of the diameters of the cavity of the true pelvis, presenting an obstacle to the effectual expulsion of a living offspring. It seems that a relative narrowing takes place chiefly in an antero-posterior direction in addition to an absolute shortening of the measurements in all the diameters. The action of the muscles on the crests of the ilia in severe cases causes inversion of their margins.

The histology of the affected tissues must next be considered.

Histology.—Briefly, the changes met with in rickety bones may be summed up thus:—they are an exaggeration of the processes normally concerned in the formation and growth of bone. As bones increase in length at the epiphysial cartilages, and in width or thickness by a deposition of matter from the deeper layers of the periosteum investing the diaphysis, these tissues are the ones chiefly concerned.

On making a vertical section through a healthy long bone (the femur is the best and most convenient bone to select) taken from a young animal, we find at either end a certain portion of the shaft segmented off by a very thin but distinct and regular line of hyaline cartilage, usually one millimetre in thickness. If the tissue at this spot be submitted to the microscope it will be found that this apparently homogeneous line of cartilage, presents *two* very distinct zones. The one farthest from the bone shaft exhibits the characteristic appearance of normal hyaline cartilage, the second, in immediate proximity to the growing bone, displays cartilage cells arranged in tiers of about six, eight, or ten, each column being separated from its fellow by a spiculum of calcareous matter. This arrangement extends the whole breadth of the epiphysial cartilage, so that in section these cellular columns are arranged as regularly as a phalanx of soldiers, and present a characteristic picture.

In rickets all this is exaggerated; a section through the epiphysis shows the line of cartilage to be several millimetres thick, instead of one; between this and the bone is a layer of variable thickness, formed of a peculiar gelatinous tissue known as the “spongioid tissue” of Guérin, possessing a bluish, translucent appearance. Examination with a microscope shows *three* zones, viz. :—

1. A layer of normal hyaline cartilage exceeding many times its healthy thickness.
2. The layer of cells arranged in vertical columns, but consisting not of ten or twelve superimposed cells, but in severe cases of rickets as many as fifty or sixty may be counted in a single column.
3. Beyond these, a layer of irregular calcareous trabeculae

enclosing here and there "islets of spongioid tissue," and tracts of hyaline cartilage.

It is the proliferation of the cells in the second layer which gives rise to "spongioid tissue." It was noted, in dealing with the morbid anatomy of this disease, that the ends of the long bones become very much enlarged; the microscopic structure affords a satisfactory explanation. If a normal centre of ossification be carefully traced, it will be found to extend from a definite spot, known as the ossific centre. The border of advancing ossification is well marked, and the cartilage clearly and regularly disappearing. Such an epiphysis as this should be termed a "discrete epiphysis." In rickets things go on in a very disorderly way; instead of the earthy matter being deposited in a definite spot, it is sprinkled irregularly throughout the terminal cartilage, so that it is no uncommon thing to find thirty or forty separate nuclei for such an epiphysis as that for the condyles of the femur. As these various nuclei become confluent, here and there little tracts of hyaline cartilage become enclosed by calcareous matter, constituting what I have termed "cartilage islets," these are often of sufficient size as to need no artificial help in detecting them. For such a condition as this the term "diffuse epiphysis" seems applicable, as implying a condition of things in which lime salts are deposited in disorder in a softened cartilaginous matrix.

Thus far observation has been limited to the ends of bones and the epiphysial cartilages, but changes no less important may be detected in connection with the periosteum. In the normal condition, the deeper layers of this tissue are adding to the bulk of the shaft by the deposition of fibrous lamellæ, which subsequently undergo ossification.

In rickets the periosteum is very thick, succulent, and trabeculæ of fibrillated tissue pass into the bone shaft but do not undergo ossification, so that in a transverse section of the shaft of a long bone, the familiar concentric lamellæ of the Haversian system is replaced by a narrow band of osseous tissue in the midst of a fibrillated matrix containing no calcareous matter whatever. This accounts for the extreme softness of the bones; later, if the disease be recovered from, all this softened tissue becomes impregnated with lime salts, and the bone becomes

actually stronger than a non-rickety one. This result is common enough in children, but a very rare event among the less fortunate monkeys.

Whether we examine the bone at the epiphysis, or in the shaft, the truth of the trite definition expressed by Sir William Jenner in speaking of the disease in children strikes us with great force:—"In rickets there is increased preparation for ossification, with an imperfect performance of that process."

The changes such as have been described here may be met with in all the epiphyses of the bones of the limbs, at the junction of ribs and costal cartilages, between the sternæ, and at the junction of the epiphysial plates of the vertebræ with their centra.

"Spongioid" tissue is most abundant at the lower ends of the femur, tibia, fibula, radius, and ulna. It is always abundant at the junction of the rib shafts with the costal cartilages. It is least in quantity in the metacarpal and metatarsal bones, and is rarely met with in any quantity at the upper epiphysis of the fibula. These facts compel one to assert that "spongioid tissue" is most abundant in the epiphyses which are near joints enjoying free and frequent movements,—to wit, the ribs in respiration, the legs and fore-arms in progression; but the head of the fibula moves scarcely at all, and there is scarcely ever any of Guérin's tissue to be found in that situation.

The effects of this early form of rickets may be tabulated thus:—

1. Deformity of the chest and beading of the ribs.
2. General thickening of the periosteum and softening of the bones.
3. Thickening of the flat bones, and occasional thinning of the bones of the floor of the cranium.
4. Enlarged epiphyses and increased curvatures of long bones.
5. Collapse of lungs.
6. *Histologically.* The development of tracts of "spongioid tissue" at the epiphysial lines.
7. Compression of the spinal cord, due, in part, to yielding of the softened vertebræ, in part to osseous deposition in the posterior surface of the bodies of the vertebræ, chiefly in the lumbar region.

RICKETS OF PUBERTY.

This is comparable to the affection known as "late rickets" in the human subject.

Observations on this form of the disease have been conducted chiefly on baboons, bears, tigers, and lions. At first I was under the impression that rickets underwent certain modifications corresponding to the species of the animal affected, but the notion was soon dispelled as my experience became wider.

Symptoms.—These are very few, but very definite. The animal shows signs of paralysis and defective dentition; gradually it becomes completely paraplegic and thoroughly helpless, and is killed on account of the paraplegia.

Visceral Lesions.—The only constant morbid condition in these cases is compression of the spinal cord, due to the bulging of the intervertebral substance, &c., into the neural canal (fig. 3). Fatty liver is frequent, and the only other constant abnormality is albumen, often in large quantity, in the urine. Phosphates are also present in great quantity, but there is considerable difficulty in obtaining the urine of monkeys in any quantity for the purposes of quantitative analysis.

Morbid Anatomy.—The pathological lesions in this form of the disease differ, in their distribution, from those described in the "Infantile" form, in a very marked form.

1. The disease may be general.
2. It may limit itself to the axial skeleton.
3. The skull alone may be affected.

1. *The Generalised Variety.*—The thorax presents the usual "rickety rosary," and in some instances even a double row of beading, due to infractions; but the chest is not deformed, as is so common in the early form.

The Skull.—It is a peculiar feature of rickets at this age, that enormous thickening of the vault of the cranium is almost constantly found, the hypertrophy limiting itself with anatomical precision to those bones of the vault of purely membranous origin; the base is rarely, in my specimens never, affected. The thickness of the parietal bone often exceeds the normal, some twelve or fourteen times. The facial bones may share in this hypertrophy, but by no means constantly.

The permanent teeth are late in erupting, due, I believe, to the thickening of the tooth-sac, shown by exposing the follicles, as in fig. 4.

The Vertebral Column.—The changes, which are of great interest, are best displayed by dividing the column vertically. This done, it will be seen that the body of each vertebra consists of three pieces, a centrum and two epiphysial plates. In health these complementary plates are separated from the centrum to which they belong by two narrow lines of hyaline cartilage throughout the period of growth. But when rickets disturbs the usual course of things, proliferation takes place here, as in the epiphysis of a long bone, and the softened tissue, bulging towards the neural canal, encroaches upon the space set apart for the cord, and compresses it. In well-marked cases the spinal cord will present alternate dilatations and constrictions, the former corresponding to the vertebral bodies, the latter to the epiphysial plates and the intervertebral discs. Fig. 3 gives a very fair exposition of this condition. This singular state of affairs is, as might be expected, most obvious in the lumbar region. From the above explanation it is clear that paraplegia in “Rickets of Puberty” arises from a very different pathological condition to that which causes paralysis in the same disease at “Infancy.”

THE APPENDICULAR SKELETON.—The bones are not, as a rule, much affected; the chief changes are to be seen at the epiphysial lines. The growing lines are irregular, but “spongioid” tissue is absent, or very small in amount. Often a distinct layer of fibrous tissue may be observed at the epiphysis. Occasionally the shafts of the long bones present patches of osteophytic bone. Occasionally the periosteum is somewhat thickened, but this is by no means common, and in the majority of cases is limited to the neighbourhood of the epiphysis.

THE AXIAL SKELETON alone may be affected. Then beading of the ribs exists, the peculiar changes at the vertebral epiphyses and thickening of the skull vault.

Lastly, the disease may limit itself to the skull alone, and occasionally the vault may be thickened without any other part of the skeleton being implicated. The thickest skulls I have yet come across are those from animals in whose skeletons no other trace of rickets could be detected.

Although the above account of rickets occurring at puberty shows "hard and fast" distinctions between this and the early form, nevertheless every degree of variety may be met with, so that an animal dying from rickets at an age intermediate to infancy and puberty would display a pathological condition of skeleton partaking of the characters of the "infantile form" in its *appendicular* skeleton, but of the "later form" in its *axial* skeleton.

The essential point of difference is, that one form in its typical manifestation affects the limbs chiefly, whereas the other attacks, more or less exclusively, the trunk and skull.

The Museum of the Royal College of Surgeons contains a collection of skulls from lions and monkeys, many of which show the thickening of the vault, such as those I endeavoured to describe; though in most of the cases there is no information concerning the other parts of the skeleton, there can be little doubt that the cause of this hypertrophy must be ascribed to rickets. In all these examples the character of the hypertrophy is very distinctive; instead of the usual arrangement into an outer compact stratum, then a layer of *dipl e*, bounded on its inner aspect by the vitreous table; the whole thickness of the bony vault is made up of porous, spongy, osseous tissue of uniform character throughout the whole extent.

An Anomalous Form.—Occasionally one meets with a condition of the long bones in monkeys which differs very materially from the varieties of rickets just described. The instances are by no means common, but important nevertheless. In these cases the animals seem near puberty. Their long bones present well-marked epiphyses, the cartilage lines are somewhat thicker than usual, "spongioid" tissue is present in small amount. The compact tissue of the bone shafts is very thin, but often firm and brittle, sometimes presenting bulgings near the middle, as though a bulb had been thrown there. The medullary cavity is very large, and in some cases is bounded below by the epiphysial cartilages, cancellous tissue being deficient or entirely absent; the medulla is diffuent, so that the condition of the long bone is as if it were an elongated nut shell containing oil. The flat bones are soft, and their edges inverted, the chest deformed, the skull tabetic, and the spine kyphotic.

The only explanation I can offer concerning these cases is—That they may possibly be examples of rickets occurring in “infancy” and that the proliferated material has undergone fatty degeneration, instead of organising. These cases are interesting, inasmuch as they present a marked similarity to the cases described by Dr Rehn at the International Congress 1881, and by Mr Barwell, in the *Transactions of the Pathological Society*, and others, as examples of juvenile osteomalacia.

The Teeth.—Long ago Mr Shaw pointed out that in the human subject, one of the results of rickets was delayed dentition ; this he attributed to the diminution of the jaws and large size of the teeth (*Med. and Chir. Soc. Trans.*, vols. xvii. and xxvi.). It was very surprising to find that in very young rickety animals the teeth were always in place, and normal both as to size and number. This is explained as follows:—Monkeys cut their milk teeth very soon after they are born, and many I believe enter the world with some of their teeth already above the gums, so that the temporary dental armature is complete before rickets has time to manifest its baneful effects.

In examples of rickets at puberty, the permanent teeth are delayed, retardation being due in all probability to extreme thickening of the dental follicle, which normally is as thin as tissue paper, but in these cases is as thick as the skin of the finger.

RICKETS OF MATURITY.

This variety is the rarest of all. Few instances have come under my notice, and these have been chiefly among the Carnivora, but the French naturalist Lataste has made some observations on the subject, which to a certain extent supply the deficiency.

Symptoms.—The most characteristic features of the disease are deformity, paraplegia, loss of teeth, and fracture of the bones of the limbs, due in some cases to brittleness and tenuity of their texture ; in other instances fracture results from softening of the bones. The disease attacks every part of the skeleton. The skull is light and porous, when macerated and dried it becomes as light as cork ; the alveolar margins of the jaws absorb, allowing the teeth to fall out prematurely. In some cases the bones

in the recent state are soft, and yield easily to a knife, but when these soft bones are dried they become so delicate in texture that they may be crushed into powder between the thumb and finger. In the majority of instances the long bones are brittle, and break easily. Curves are commonly found in the long bones of the limbs. Deformity of the chest is uncommon.

The interspaces of the cancellous tissue are large. In rodents living in captivity this affection seems fairly common, affecting more particularly the females, and Lataste found that in his specimens the bones were soft, and cut as easily as gelatine.

It should be carefully noted that care is very necessary in drawing conclusions from dried museum specimens. Frequently have I observed bones, which were as soft and as flexible as gutta percha when recent or kept in spirit, become hard, brittle, and porous when dried for the museum shelves. Hence it is an important point to keep typical examples of bone disease in a moist condition. It appears exceedingly probable that very many of those porous, mortary-looking skulls and bones exhibited in museums as examples of "Osteoporosis" were, when recent, really soft and yielding bones in many instances. That there is some foundation for such an opinion will be shown by some cases now to be described.

Mr Solly, in his well-known paper in the *Medico-Chirurgical Society Transactions*, xxvii., writes as follows:—"I find that mollities ossium is not confined to the human species; for I have learnt from Mr Spooner, the Professor of Anatomy at the Veterinary College, that a year or two ago they had some hounds there belonging to Lord Middleton, the bones of whose skeletons were softened, the disease attacking one bone after another. A *post-mortem* examination of the bones exhibited the same morbid appearance I have described as occurring in the human subject—the deposit of red matter and great vascularity of the cancellated and laminated structure of the bone."

The "*Veterinarian*," for September 1860, contains a "paper," by Varnell of the Veterinary College, London, entitled:—"A peculiar and unusual disease of the osseous tissue in the horse: resembling, in many of its characteristics, mollities ossium, rachitis, osteoporosis, and fatty degeneration of bone."

In the very careful account given of this specimen, the follow-

ing facts are of the greatest interest:—The bones generally were so soft that they could be cut with a knife in any direction, with the greatest ease. The cancellous spaces were filled with a red gelatinous substance.

The animals were four and five years old.

The skull is preserved in the Museum of the Veterinary College, London, with some other skulls and bones similarly affected, which, through the kindness and courtesy of Principal Robertson, I have had every opportunity of examining. Mr Varnell's original specimen was exhibited at the Pathological Society of London, and is described in the *Transactions* for the years 1859–60. The lower jaw is preserved in the Museum of University College, London. Careful examination of all the specimens has convinced me that these bones were affected with "rickets of maturity," and that the peculiar "osteoporotic" appearance they present is produced by maceration and subsequent drying.

Mr Varnell, in his very clear account in the *Veterinarian*, distinctly states that "the bones were soft, and could easily be cut with a knife." At the present time these bones present the dry mortary appearance so characteristic of the so-called "osteoporosis."

Microscopically these specimens show enlargement of the cancellous spaces and Haversian canals, the latter often being separated from neighbours by a very thin lamina of osseous tissue.

By far the most interesting of these cases is one reported by Paul Gervais, in the *Journal de Zoologie* for 1875. It concerns some bones found near Vienna, which Brandt, in the *Cetaceen Europa's*, 1873, considers to belong to the Cetacea, and names it *Pachyacanthus*. From the figures given by Gervais the ribs and vertebræ present a condition allied to this so-called "osteoporosis;" but the vertebræ are remarkable, inasmuch as they show a considerable narrowing of the spinal canal, so that the spinal cord must have been much compressed by the obvious overgrowth of osseous material. It was through carefully following this case that I was led to explain the cause of paraplegia in rickety animals. Before perusing the account of this case the existence of general narrowing of the canal for the cord by bony overgrowth or softening of the component vertebræ seemed too strange and novel; but, as has been shown in the preceding

pages, the application of information thus gained was crowned with the happiest and most satisfactory result, and has afforded a clear explanation of a symptom which, though well recognised as such, had never had its cause investigated in a proper way. This narrowing and yielding of the vertebræ throws light on symptoms observed in "osteomalcia" in the human subject. In this formidable malady pain is a prominent symptom, and careful examination of the clinical histories of the reported cases shows, that in the majority of cases, pain, agonising in its characters, began in the lower extremities, and in some cases the patients became paraplegic. No doubt, in these cases the yielding vertebra caused the spinal nerves to be compressed, for the lumbar vertebræ were softened, as proved at the autopsy, and the pain was always increased on movement.

That this condition of cord and vertebræ may be overlooked is easy to understand. So long as I followed the usual *post-mortem* routine and opened the neural canal from behind, I failed to observe the true "state of affairs," but when, on making transverse section of the column, leaving the cord *in situ*, the relative condition of bone and spinal marrow were observable and the condition recognised.

ÆTIOLOGY.

In the human subject there can be no doubt that many things, but no one thing in particular, conspire to produce rickets. Poverty and hard living are no doubt factors in the case, bad hygienic conditions, unsuitable feeding, and especially depriving the child of the breast-milk of the mother, are powerful causes. Frequent pregnancies, with slight intervals, are predisposing if not actual causes of rickets in the offspring.

There can be no doubt that the same list of causes operate in producing rickets in animals. They are taken, many of them when quite young, from the mother, and fed on unsuitable diet; they suffer loss of exercise, and are exposed to the vicissitudes of an English climate.

That unsuitable diet plays a very important part in the production of rickets in children and in animals, may be illustrated by two cases. I saw a *post-mortem* on a boy aged five years, who died as rickety as it is possible to imagine a child. The

boy's only desire was to be fed on sausages and bread, with gin to drink, such as his miserable parents had been accustomed to give him. That same day I made an examination of a young bear, eighteen months old, with rickety changes in every bone; it had been taken quite young from its mother, and brought up on board ship to eat boiled rice. The two cases were good examples of the vicious effects of improper food.

When a wild animal becomes a prisoner, it is in most cases impossible to provide the creature with that variety and quality of food which it obtains when in its wild state.

Not long ago some fine examples of the Babirusa were presented to the Zoological Society; seven months later, a fine male died, with all the bones spongy and soft, as the monkeys' skeletons described in the earlier part of the paper.

Lataste's observations on the Gerbilles show in the most conclusive manner that rickets is a result of captivity, and the longer the animals remained in the captive state the earlier the offspring showed symptoms of rickets. Gerbilles, born in the desert, then confined in cages, became rickety in two years, but those born in confinement succumbed to the disease in fifty-two days.

Principal Robertson, of the Royal Veterinary College, London, informs me that dogs are often subject to rickets; and he considers that want of exercise, unsuitable food, and what is termed "in-and-in-breeding," are powerful causes in producing the disease.

The case of the Gerbilles is a very good example of in-and-in-breeding. Then there is the question of frequent pregnancies, weakening the mother and drawing on her store of lime salts.

A gentleman, who lived for eleven years on the West Coast of Africa, and still resides there, assured me that rickets was unknown, and that after a woman is delivered of a child she is kept apart from her husband for one year.

Respecting the causation of osteomalacia in the human subject, most observers have pointed out the association of frequent pregnancies with this formidable disease, so with regard to the Gerbilles, the females who were most prolific succumbed earliest to the affection.

GENERAL CONCLUSIONS.

The facts and deductions set forth in the preceding pages have been made from observations on a large number of animals of various species.

Since December 1881 to the present time more than 200 monkeys have been examined *post mortem*. The proportion of rickets in the last hundred *Quadrumana* was 50 per cent.; this means that half the animals kept in confinement in this country for any length of time die rickety.

Almost the same may be said of the *Carnivora*, particularly the smaller species, *e.g.*, *Cynictis*, *Ichneumon*, *Binturongs*, &c. Bears are not exempt from the affection. Rodents suffer greatly, old and young. Instances of the disease occur in birds and in lizards, so that, zoologically, the disease is fairly well distributed.

Reviewing the facts broadly, it is obvious that the forms described as "Rickets of Infancy" and "Rickets of Puberty" are the same diseases, modified according to the normal physiological process in operation at the age at which the perturbation manifests itself,—the abundance of material enabling one to set this question definitely at rest.

With regard to the form of the disease occurring at maturity, there can be little doubt that this is the result of similar causes, the effects being also modified by the altered condition of the skeleton incident to the adult state, and as each of the three phases of life—infancy, puberty, and maturity—is characterised by peculiar skeletal modifications, so do the effects of disease declare themselves in a special manner coincident with the age of the subject.

These facts also go to show that in the human subject "rickets," "late rickets," or "juvenile osteomalacia," and "mollities ossium" are the result of malnutrition, the effects on the skeleton varying with the age of the patient, and though clinically they present different features, nevertheless pathologically they must be considered identical, inasmuch as the fundamental character in all three is perturbation of the physiological processes concerned in the formation, growth, and nutrition of the skeleton. The following table is constructed to show

the leading pathological tendencies of the disease according to the age at which it occurs.

Table to indicate the Distribution of the various Lesions according to Age.

	INFANCY.	PUBERTY.	MATURITY.
<i>Skull,</i> . .	Soft and somewhat thickened at the vault. Exterior may present a worm-eaten appearance. The base often presents tabetic patches.	Vault is thickened.	Softened generally and eroded.
<i>Vertebrae,</i> . .	Spongy and soft, encroach on the neural canal, causing paraplegia.	Present bulgings at the discs and epiphysial plates. Paraplegia.	Soft, spongy, and vascular. Paraplegia.
<i>Thorax,</i> . .	Deformed and beaded. Infractures of ribs.	Beaded. Infractures of ribs.	<i>Nil.</i>
<i>Long bones,</i> . .	Soft, curved, with large epiphyses. Spongioid tissue reaches its maximum.	Fibrous tissue in a thin layer at the epiphysial line. Spongioid tissue in a minimum degree,	May be often soft and curved, or the compact tissue exceedingly thin and brittle.
<i>Teeth,</i> . .	Temporary set. Normal.	Permanent set late in erupting.	Fall out prematurely, due to absorption of the sockets.

FOETAL CRETINISM.

The subject of rickets cannot be passed over without some allusion to a disease which in many points seems to be closely allied to it, yet in other respects is so very different. On account of the resemblance it bears to rachitis, it has been called "foetal rickets" by some authors, but other pathologists refuse to regard it as such, and consider the affection as being of the nature of cretinism.

Professor Eberth has written a monograph on the subject, entitled *Die Foetale Rachitis und ihre Beziehungen zu dem Cretinismus*, 1878, and describes a case which he had met with in a calf. Specimens have been investigated by Müller and Urtel. In this country examples of the disease, under the name

of "foetal cretins," have been shown at the Pathological Society by Dr Barlow, Messrs Shattock, Bowlby, and the writer (see vols. xxxii. and xxxv.).

The subject has been mentioned here, because the disease undoubtedly occurs in animals. In addition to Müller and Eberth's observations on calves, Shattock has drawn attention to a foetal bitch puppy in the Teratological Series of the Royal College of Surgeons' Museum, London.

It seems to me that, as rickets is so very frequent in animals, not only Quadrumana, Rodentia, and Carnivora, but it also occurs with tolerable frequency in horses, mules, lambs, &c., it may reasonably be expected that examples of these curious foetuses ought to turn up now and then if the disease be really due to rickets occurring *in utero*. So far as I have been able to observe at the Zoological Gardens, none of the young born there have exhibited this condition of the skeleton in the slightest degree, although the number of still-born animals is not by any means small. On the other hand, there are many points in the anatomy of the disease associating it with cretinism, but there is not a sufficient number of cases on record to enable a true verdict to be given. This fact should stimulate those who have opportunities in this direction to be on the look out for cases occurring among mares, ewes, cows, &c., and to have them carefully dissected, described, and recorded in accessible places. Up to the present time I am unaware of any progressive case of intra-uterine rickets having been observed. Until this be done there is not a tittle of evidence to warrant the "rickety" origin of these singularly interesting malformed foetuses of man and animals.

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2. *Veterinarian*, 1860. This contains Varnell's account of a peculiar disease of the osseous system in the horse.
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For a full account of *Pachyacanthus Suesii*, reference must be made to a paper by J. F. Brandt, published in the *Mémoires de l'Académie Impériale des Sciences de Saint-Pétersbourg*, tome xx., 1873, entitled "Untersuchungen über die fossilen und subfossilen Cetaceen Europa's."

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Those who wish for details concerning individual cases of rickets in animals I must refer to my original papers in the *Trans. Path. Society*, vol. xxxiv. The forthcoming vol. xxxv. contains two papers on the subject, detailing a far wider experience of the disease. All the communications are illustrated by numerous woodcuts.

The *Proceedings of the Zoological Society* for March and April 1884 contains full details of the disease as it occurs in Carnivora.

Several complete skeletons are exhibited in the Pathological Series of the Museum of the Royal College of Surgeons, and typical examples of the disease are preserved in the Museum of the Middlesex Hospital, and at Cambridge.

Perhaps one cannot do better than close this paper with a quotation from Otto's *Human and Comparative Pathological Anatomy* (South's translation, 1831). It runs as follows:—"As, however, man forms but one link in the chain of organic beings, so for the perfection of pathological anatomy nothing would operate more advantageously than the investigation of the diseased structure of other organic bodies, and particularly those of animals. As soon as we have collected a considerable number

of such observations we may expect, in a general view of the vices of structure in organic bodies, to penetrate deeper into their nature and causes. Even now, whilst pathological anatomy, in comparison with most other medical sciences, is only in its infancy, its utility is traced in almost all the branches of medicine. It is the common and absolute source of all, but particularly of anatomy, physiology, and pathology."

EXPLANATION OF PLATE XVIII.

Fig. 1. The spinal column, thorax, and pelvis of a monkey affected with rickets ($\frac{1}{3}$ natural size). It shows the lateral compression of the thorax and the approximation of the symphysis pubis, and the xyphoid cartilage of the sternum, due to the kyphotic curve of the spine.

Fig. 2. Femur from a monkey affected with rickets (natural size), showing enlargement of the epiphysial cartilages, an abundance of "spongioid tissue" *s*, and two cartilage islets *C.I.* in the epiphysis.

Fig. 3. Longitudinal section of the posterior dorsal and two lumbar vertebræ of a sloth bear at puberty (natural size). The figure shows the proliferation of tissue between the complementary plates and centrum of individual vertebræ, giving rise to compression of the cord.

Fig. 4. Lower jaw of a baboon. The teeth above the alveolar margin belong to the "temporary" set. At the posterior portion of the maxilla the bone has been removed, so as to expose a "permanent" tooth in its follicle; the "sac" walls are much thickened, and more fibrous in character than in the normal condition.

ON THE PRESENCE OF PEYER'S PATCHES (*GLANDULÆ AGMINATÆ*) IN THE CÆCUM AND COLON OF CERTAIN MAMMALS. By G. E. DOBSON, M.A., F.R.S.

IN Professor Flower's Lectures on the "Organs of Digestion in Mammalia," it is stated that "the solitary glands are found scattered irregularly throughout the whole alimentary tract; the agminated, on the other hand, are always confined to the small intestine, and most abundant in its lower part,"¹ and this statement appears still to represent, fairly accurately, the present amount of information we possess on the distribution of these so-called glands, for the existence of a pair of Peyer's patches in the immediate vicinity of the ileo-cæcal valve, noticed by the late Professor Rolleston in the rabbit,² and figured by Mr W. N. Parker in both the rabbit and hare,³ can scarcely be considered as very prominent exceptions to the general rule.

While investigating the anatomy of the Insectivora, I was surprised to find in species of two families, *Chrysochloridæ* and *Talpidae*, patches of agminated glands situated at intervals throughout the whole intestinal canal, from the duodenum even to the rectum, and subsequent examinations of species of other orders has demonstrated that this peculiarity is not confined to Insectivora.

The first species in which the presence of Peyer's patches in the colon was observed by me, was in the great water mole (*Myogale moschata*) of South-Eastern Russia. In this animal the mucous membrane of the rectum, immediately before the latter enters its glandular sheath, presents on the side opposite the attachment of the mesentery a large oval patch of agminated glands,⁴ about 18 mm. by 10 mm., including nearly one hundred follicles, while, neither in its neighbourhood, nor, indeed, for 9 cm.

¹ *Medical Times and Gazette*, 1872, i. p. 219.

² "Harveian Oration" for 1873, published in *British Medical Journal* for that year, ii. p. 2, fig. 1.

³ *Proceedings of the Zoological Society*, 1881, p. 625, pl. liii. figs. 1 and 3.

⁴ See my "Monograph of the Insectivora, Systematic and Anatomical, pt. ii., pl. xxii. fig. 5 d (1883).

higher up, is there any trace of the minute zig-zag elevations of the mucous membrane, which, in most species of *Talpidae*, take the place of villi. The next large patch is about 12 cm. higher up; it is of precisely the same character, but smaller, and placed in the midst of fine zig-zag elevations. In the desman of the Pyrenees (*Myogale pyrenaica*), which so closely resembles *M. moschata* in its anatomical characters, a similar patch occupies the rectum. In *Gymnura rafflesii* a large patch, including about forty follicles arranged in rows parallel to the long axis of the intestine, is placed between three of the prominent parallel longitudinal ridges of the mucous membrane, in the terminal fourth of the canal, in a part destitute of villi, the walls of which present the usual appearance of that of a colon,¹ although there is no ileo-colic valve or other constriction separating it from the villous upper part; besides this, two other patches only are found in the whole length of the intestine, of which the most anterior is very large, about 18 mm. by 10 mm., and placed about 15 cm. behind the commencement of the lower half of the canal; both these patches are surrounded by well-developed villi, so that they may be said to occupy the lower part of the ileum. In the golden mole (*Chrysochloris villosa*) cylindrical villi cover the whole mucous surface of the intestine from the pylorus to the rectum, while in the posterior extremity of the canal three patches of agminated glands appear surrounded by densely set villi, which also occupy the spaces between the follicles on the surface of each patch, of which the most posterior is situated on the free side of the intestine about 25 mm. from the anal orifice.

It may be said that these species of Insectivora possess no colon, as there is no difference in calibre between the upper and lower parts of the intestine, and no indication of an ileo-colic valve, and that, although these patches extend even into the rectum,

¹ In animals not possessing an ileo-colic valve, the presence of these longitudinal ridges of the mucous membrane, coincident with the disappearance of the villi sufficiently indicates the commencement of the colon. Thus in the dormouse (*Myocerus avellamarinus*), an animal belonging to the only family of rodents not possessing a cæcum, although there is no trace of a valve, the exact position of the commencement of the colon is indicated by the abrupt termination of the long cylindrical villi (which densely cover the whole mucous membrane of the upper three-fourths of the intestine), and the commencement of the ridges referred to.

into a part not occupied by villi, yet this indicates no exception to the general rule as above stated.

In the rodents, however, where (with the exception of the *Myoxidae*) a well-developed ileo-colic valve exists in all species, the presence of Peyer's patches in the cæcum and colon (of some species at least) is capable of demonstration.¹

In the common water-vole (*Arvicola amphibius*), in the distal extremity of the immense cæcum, is a prominent patch of agminated glands, occupying a space of 6 mm. by 4 mm., and including about thirty-five follicles, then follow (at intervals varying from 35 mm. to 45 mm.) three smaller patches, the highest up being about 23 cm. from the ileo-cæcal valve. At a distance of about 23 cm. from the ileo-cæcal valve the first patch, distinctly Peyerian, occurs in the colon; beyond this, other small patches appear at intervals varying from 6 cm. to 3 cm. On the other hand, in the field vole (*Arvicola sylvaticus*), in which the cæcum is rather short, I can find but a single patch, including about ten follicles, in the distal extremity of the cæcum, and a small one with four, in the lower third of the colon. In the harvest mouse (*Mus messorius*), which has comparatively a still shorter cæcum, there is no trace of Peyer's patches in either cæcum or colon. In the distal extremity of the stomach-like cæcum of the jerboa-rat of India (*Gerbillus indicus*) is a well-defined Peyer's patch, 6 mm. by 4 mm., containing thirty-three follicles. This patch scarcely differs in appearance from the lowermost in the ileum: in the colon there are two patches, one about 8 cm. from the cæcum, the other 6 cm. from the anus; the anterior includes about thirty follicles, the posterior fifteen. These follicles differ from those in the cæcum and ileum in being spread over a comparatively wider patch of intestine, which has less sharply defined margins.

About forty Peyerian patches, varying in size from some with twenty-five to others with five follicles, occupy the cæcum of the prehensile-tailed porcupine (*Cercolabes prehensilis*), being situated chiefly on the free side of the gut from its cæcal

¹ My observations as to the true nature of the patches of agminated glands found by me in the cæcum and colon, namely, that they correspond in structure to the Peyerian patches in the ileum of the same animals, have in each case been verified by my friend Dr T. R. Lewis, whose special acquaintance with the histological characters of the intestinal tract is so extensive.

extremity to the colon, none being in the vicinity of the ileo-cæcal valve, and extend into the colon where they are still smaller, few including more than five follicles, lessening in number towards the rectum, the last being placed about 17 cm. from the anus.¹

In *Cavia flavidens* the only patch in the cæcum is an enormous one about 12 mm. in diameter, placed nearly opposite the ileo-cæcal valve; about the middle of the colon are three small patches about 5 cm. apart. In the specimens of *Sciuropterus* and *Dipus* examined, no patches were found in either cæcum or colon.

In *Manis tricuspida* there is a large patch at 5 cm. from the anus; there are no villi in the neighbourhood of this patch, but at a short distance above it they appear. It must, however, be noticed that, immediately below the patch referred to, there is a constriction of the gut which may represent the ileo-colic valve, in which case the colon would only measure about 5 cm.

In *Microcebus smithii* a prominent patch, including six follicles, is found towards the middle of the cæcum (which is about 25 mm. long). This patch closely resembles the lowermost of the two patches in the ileum, which is situated about 3 cm. above the ileo-cæcal valve. It is noticeable that this patch (in the ileum) is placed at the bottom of a wide pouch, and that at the entrance to and opposite to the mouth of the pouch the long cylindrical villi cease abruptly, as if shorn off by a razor, so that, when the intestine is laid open, a square patch of mucous membrane, in the centre of which is the pouch, is seen to be devoid of villi. No Peyer's patches occur in the colon proper.

I regret that I have neither opportunities nor time for examining a larger series of specimens, but the few instances brought forward above sufficiently show that exceptions to the general rule that Peyer's patches exist only in the small intestine are not very rare, and that it is probable that these exceptions

¹ Similar patches exist in the colon of *Erethizon dorsatus* which have been thus described by Professor Mivart, who, however, has not recognised them as *glandulæ agminatæ*:—"In the first 5 feet of the large intestine there is a series of glands, from 1"·2 to 3"·8 apart, situated along the free margin of the gut. Each consists of a little aggregation of from three to five crypts."—*Proc. Zool. Soc.*, 1882, pl. 275.

may prove still more numerous when careful examination of the intestinal tract of many more species of mammals shall have been made, which I trust the facts brought forward in this short paper will induce others to undertake.¹

¹ Whilst this paper is passing through the press Mr F. E. Beddard informs me, in reply to my inquiries, that he finds in *Haplalemur griseus* Peyer's patches extending a long way down the colon.

ON THE "INVISIBLE BLOOD CORPUSCLE" OF NORRIS.

By J. LOCKHART GIBSON, M.B., C.M., *Senior Demonstrator of Physiology, University of Edinburgh.*

IN a book entitled *The Physiology and Pathology of the Blood*,¹ Dr Norris asserts that he has been able to demonstrate the existence of "invisible corpuscles" in that fluid, and describes some ingenious methods of examination which, he says, have enabled him to bring these corpuscles into view.

I have made some observations upon this subject, and I believe these will show that the existence of such corpuscles cannot be proved by the methods adopted by Dr Norris.

Dr Norris bases his methods chiefly on three conditions.

1st. The blood must be examined in very thin layers, in order that there may be only a single layer of corpuscles.

2nd. Either the liquor sanguinis must be removed from around the corpuscles (because "it has the same refractive index as the invisible corpuscles") or the refractive index of the liquor sanguinis must be altered.

3rd. Dr Norris regards the staining of these so-called "invisible corpuscles" as of great advantage.

I believe I have been able to meet all these three conditions; and I have also met another which is most important in such observations, viz., the enumeration of the corpuscles.

I cannot understand how Dr Norris could feel justified in coming to a conclusion regarding the existence of an "invisible corpuscle" in the blood without adding to his methods the simple one of enumeration, more especially as none of the methods he uses for bringing this corpuscle into view is free from fallacy.

First, I have to find fault with the methods used by Dr Norris for obtaining a single layer of corpuscles, and for, at the same time, removing the liquor sanguinis from around the corpuscles. The two chief methods which he employs for this purpose he has termed "Packing" and "Isolation."

¹ By Richard Norris, M.D. Smith, Elder, & Co., London, 1882.
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(1) *Packing*.—A cover-glass one surface of which is slightly convex is chosen, and is strapped, with its convex surface downwards, upon a glass slide, so firmly as to produce a series of Newton's rings; and the strapping is so arranged that the rings are elongated and cross the cover-glass completely. Under one side of this cover-glass the blood is introduced.

In Dr Norris's own words:—

“Two objects are gained by this arrangement. 1st. The glasses are everywhere in such close proximity as to admit the corpuscles flatways, and in single layer only. 2nd. In the part occupied by Newton's rings the proximity is much less than $\frac{1}{10,000}$ th of an inch, and thus presents a barrier to the passage of the corpuscles, whilst allowing free passage to the liquor sanguinis.”

By this means the corpuscles are kept on one side of the Newton's rings, whilst the liquor sanguinis is filtered off to the other side.

The coloured corpuscles are crowded together, that is, “packed;” and amongst these crowded corpuscles many pale, colourless, and almost invisible forms are seen. These pale corpuscles are the “invisible corpuscles” of Norris, which he believes have been brought into view by the removal of the liquor sanguinis from around them (the liquor sanguinis having the same refractive index as the corpuscles).

(2) *Isolation*.—A square cover-glass of large size is strapped down at two opposite sides to a slide with a hole in its centre. The blood is introduced either by the hole or under the margin of the cover-glass. A plug is then so passed through the hole as to push up the cover-glass in its centre. When this is done, the liquor sanguinis and many of the corpuscles are drawn by capillary attraction towards the sides of the cover-glass, while the rest of the corpuscles adhere to the part of the cover-glass which has been lifted up, and can therefore be examined free from the liquor sanguinis which surrounded them. Dr Norris says that the “invisible corpuscles” are more adhesive than the ordinary red corpuscles, so that a large proportion of those which adhere to the cover-glass are “invisible corpuscles.”

Any one who gives these methods a careful and unbiassed consideration will at once see that they are liable to a very important source of fallacy. It is, I believe, impossible to use

force sufficient to remove the liquor sanguinis from around the corpuscles without a great probability of some of the colouring matter of the corpuscles being at the same time withdrawn from them, and coloured corpuscles deprived of their hæmoglobin present the same appearances as the "invisible corpuscles" of Norris.

In trying, therefore, to assure myself as to the presence of these corpuscles in the blood, I had recourse to two other methods used by Dr Norris, which, it appeared to me, would, with one essential modification, yield satisfactory results.

These two methods are—(1) the alteration of the refractive index of the liquor sanguinis, and (2) the staining of the so-called "invisible corpuscles."

I met Dr Norris's conditions as follows:—

1st. By means of Gower's hæmocytometer cell, I obtained, not indeed an extremely thin layer of fluid, but, what was wanted, a single layer of corpuscles.

2nd. I used a saturated solution of sodium chloride, which Dr Norris recommends for altering the refractive index of the liquor sanguinis, and so bringing his "invisible corpuscles" into view. Instead, however, of merely mixing the solution with a drop of blood, I substituted it for the sodium carbonate or sodium sulphate solution, of sp. gr. 1022, which is commonly used for diluting blood for the enumeration of its corpuscles. (This, I subsequently found, had already been done by Dr Alice Hart.)

When blood is mixed with the ordinary sodium carbonate solution in the mixing cell of a hæmocytometer, the resulting mixture has a flaky appearance, due to the suspended corpuscles. And when, instead of the sodium carbonate solution, a saturated solution of sodium chloride was mixed with the blood, it was found that immediately after the mixture the appearance was practically the same as that with sodium carbonate solution. After a quarter of an hour, however, the mixture began to lose its flaky appearance and to become clearer. An estimation of the corpuscles at this time showed that, instead of the normal number of red corpuscles, 8,000,000 odd (the animal was a dog), only 5,000,000 odd were to be found in a cubic millimeter of blood. The corpuscles were peculiarly fixed and stiffened, and many of them were very pale.

In from half an hour to an hour after the mixture of the blood with the solution, the contents of the mixing cell had almost entirely lost their flaky appearance, and only a clear hæmoglobin-tinted fluid remained. An estimation of the corpuscles at this time showed only 1,000,000 odd corpuscles per cubic millimeter of blood. After the mixture had been allowed to stand for eighteen hours, the fluid was found to be still clearer, and only 400,000 corpuscles could be counted in a cubic millimeter of the blood. It is obvious, therefore, that the salt solution dissolves some of the red corpuscles very rapidly, and others more slowly; and it is not difficult to understand that corpuscles undergoing solution should appear paler and less visible than the rest. It is in any case quite evident that such a solution is an entirely inappropriate one to use in a search for an "invisible corpuscle" in the blood.

3rd. In my efforts to stain this so-called "invisible corpuscle," I attempted to observe all Dr Norris's conditions. I used, in accordance with his injunctions, a very weak solution of aniline blue—.04 per cent. in a $\frac{3}{4}$ per cent. solution of common salt (Dr Norris often used 10 per cent. of the blue).

I took the blood into the pipette while it was running from the puncture, and mixed it rapidly with the diluting fluid.

After a quarter to half an hour, a drop of the mixture was examined, and it was found that the solution of the colouring matter was so weak that the layer in the hæmocytometer cell appeared practically colourless under the microscope.

The first appearance of the field after the corpuscles had settled was very striking, and at the first glance seemed to support Dr Norris's views; for I found that in each division of the hæmocytometer cell there was an average of from nine to ten corpuscles which were deeply stained by the aniline blue. The rest of the corpuscles had the colour of ordinary coloured corpuscles. Upon counting the corpuscles, however, it was found that the numbers of the tinted and the numbers of the untinted had to be added together, in order to obtain the number of corpuscles found in each square when no staining fluid is used.

On proceeding with the enumeration, I found that a greater and greater proportion of the corpuscles became coloured by the aniline blue; and by the time I reached the twentieth division

of the cell every corpuscle was more or less tinted of a blue colour.

The total number of corpuscles per cubic millimeter of blood was identical with the number found in many enumerations of the same blood under the ordinary methods of examination, viz., with carbonate or sulphate of soda, sp. gr. 1022, or a $\frac{3}{4}$ per cent. solution of sodium chloride.

Dr Norris having discovered, as he thinks, an "invisible corpuscle" in the blood, proceeds to find grounds for stating that it is the precursor of fibrin, and that it goes through stages of "spreading," "granulation," &c., previous to the true fibrin formation. Perhaps it is hardly necessary to attempt to refute such a theory, when, as I believe, no such corpuscle exists. But I think it may be interesting to state one fact which it seems to me does not receive the attention it deserves from those who ascribe fibrin formation to the transformation of a corpuscular element in the blood. This fact is, that hydrocele fluid, which does not clot spontaneously, but which can be made to clot by the addition of a little fibrin ferment, contains no constant constituents of a cellular or corpuscular nature. Moreover, from hydrocele fluid a precipitate of "fibrinogen" can be thrown down, as it can from blood plasma, by saturating the fluid with common salt; and a solution of this fibrinogen will clot on the addition of fibrin ferment.

Dr Norris states, as an explanation of the power of saturated solution of neutral salts to prevent coagulation of the blood, that they prevent his "invisible corpuscles" from undergoing the changes which lead to the production of fibrin—preserve them, in fact, in their original form. I have shown that a saturated solution of one neutral salt, instead of preserving the corpuscles, dissolves most of them.

The most feasible explanation of the power of saturated solutions of the neutral salts to prevent coagulation is found in the fact that they precipitate fibrinogen, and that it is not until this precipitated fibrinogen is redissolved, as by the addition of water, that coagulation can take place, i.e., that the fibrinogen can assume the form of fibrin under the influence of the fibrin ferment.

Dr Norris argues that the so-called "invisible corpuscles"

of the blood, which he believes to be young red blood-corpuscles, are derived from the nuclei of what he calls "primary lymph corpuscles" (nucleated white corpuscles found in the lymph glands and spleen), which have lost their surrounding cell protoplasm, and have taken on a discoid form, previous to being discharged into the blood, where they become coloured. Dr Norris further considers that he has found evidence to prove that there are bodies in oviparous and amphibian blood which are identical with the "invisible corpuscle" of mammalian blood. These bodies also he considers to be derived from the nuclei of the "primary lymph corpuscles." He says that the nuclei of these "primary lymph corpuscles" contain each a nucleolus; that the nucleus becomes extruded from its surrounding protoplasmic sheath (or that the sheath breaks up); that the escaped nucleus enlarges, assuming at the same time an ovoid form; and that the nucleolus becomes more evident and ovoid, and acts as a nucleus to this body, which is perfectly colourless, and very difficult to see. This process, according to Dr Norris, may occur either in the blood glands or after the "primary lymph corpuscles" are discharged into the blood.

I cannot do better than quote Dr Norris' own words (p. 186, footnote):—

When we examine the fresh blood of a frog or triton, we invariably see numbers of oval bodies which look like nuclei, and have the same appearance as those seen in the red corpuscles. These bodies are in reality the nuclei of colourless ellipsoids, in many cases as large as the red corpuscles; but their cellular margins are so colourless, smooth, and transparent, and their refractive index so akin to the liquid in which they lie, as to be wholly invisible, and incapable also of being photographed. . . . I have found these corpuscles to be present in all classes of the ovipara, birds, fish, batrachia, and other reptiles. They are the ultimate and most developed products of the spleens and bone marrows, and come over into the blood in a colourless state, there to acquire hæmoglobin.

It is with some diffidence that I presume to criticise this paragraph; for it seems to me to betray such an imperfect acquaintance with the appearance of a preparation of frog's or newt's blood immediately after, and soon after its removal from the body, that I fear I may be misunderstanding Dr Norris's meaning.

It must be known to any one who has examined specimens

of frog's, newt's, &c., blood, that there are three very distinct and different conditions of the coloured blood-corpuscles, according to the time of examination of the blood after its removal from the body. Immediately after the blood is drawn, no nucleus can be seen in the coloured corpuscles. Very soon, however, a colourless oval body makes its appearance in each corpuscle; and if these distinctly nucleated corpuscles be watched, the nuclei will be seen passing towards their periphery, and ultimately becoming extruded into the surrounding fluid, where they exist as *free nuclei*. The longer the preparation stands, the greater will be the number of free nuclei seen in the field. The corpuscles from which the nuclei have been extruded can be easily seen, for the envelope does not rupture to allow the nucleus to pass out.

I think that all the free, or "apparently free," nuclei found in the field can be accounted for in this way; and that Dr Norris will have to bring forward much more conclusive proof than he has yet done, before any of them can be accepted as the nuclei of colourless, ovoid, invisible corpuscles.

It will be seen, from what I have said of Norris's corpuscles, that I do not consider them to be identical with the Blutplättchen of Bizzozero (Hæmatoblasts of Hayem). These latter I am much more inclined to look upon as *white corpuscles* that have broken down, possibly previous to the liberation of the fibrin ferment.

ON THE EYE OF *ORNITHORHYNCHUS PARADOXUS*.

By R. MARCUS GUNN, M.A., M.B. (Edin.), F.R.C.S.

(PLATE XIX.)

Two eyes that had been preserved in whisky were handed to me for examination.¹ They were unopened, and had a little orbital fat adhering to them, as well as short pieces of the muscles, but the latter were too imperfect and fragmentary to be of service.

The eyeball is small, measuring only about six millimetres in its greatest transverse diameter. The fact that the cornea had sunk inwards considerably from the action of the spirit prevented the determination of its curvature, and rendered the antero-posterior measurement of the globe uncertain.

The posterior part of the eye is found to be mainly protected by a cup of hyaline cartilage, instead of the usual sclerotic coat met with in other mammals. This cup is thickest at the bottom, near the optic nerve entrance; and its sides become gradually thinner as we pass forwards, until they end in a sharp rim just posterior to the ciliary region. The cartilage is lined on both surfaces by a layer of fibrous tissue. These two fibrous coverings increase in thickness anteriorly, and, on the termination of the cartilage, they join. The single fibrous coat so formed, is prolonged forwards as an ordinary sclerotic, becoming continuous with the tissue of the cornea in the usual manner. Several apertures occur in the cartilage; one is for the entrance of the optic nerve; the others, situated a little posterior to the equatorial region of the globe, serve for the passage of the large vasa vorticosa. All these apertures are as nearly as possible of the same size, each measuring half a millimetre in diameter. Where the cartilage is thus interrupted, there is a local increase of the fibrous tissue. The muscles of the globe are inserted just behind the rim of the cartilaginous cup, their tendons joining the fibrous tissue and contributing to its increased thickness in this situation.

Cornea.—In general structure, the cornea is like that of other

(1) I have to thank Mr J. E. Sinclair of Ealing for kindly placing these eyes at my disposal.

mammals, being covered by a stratified epithelium, and bounded internally by a posterior elastic lamina and a single layer of epithelium. It is very thin compared with the sclerotic, having only a thickness of $\frac{1}{20}$ th of a millimetre in the centre, and $\frac{1}{10}$ th of a millimetre at its periphery. Twelve distinct lamellæ of fibrous tissue can be counted in a thin vertical section of the substantia propria.

The ocular *conjunctiva* is deeply pigmented in places, the pigment being contained chiefly in altered columnar epithelium cells of the deeper layer.

There is a well-developed nictitating membrane, which is capable of going over the entire cornea.

Choroid Coat.—In sections through the ocular tunics, this coat is a very conspicuous object from its thickness and dense pigmentation. It consists mainly of a fibrous stroma, with large pigment cells disposed in groups, these being especially thickly placed in its outer part. It cannot be readily separated from the inner surface of the sclerotic, with the fibrous membrane lining which its stroma is directly continuous. The outer part of the retinal pigment epithelium generally adheres to its inner surface (Plate XIX. fig. 3, *a*), forming a uniformly dark even line; the rest of this epithelium, including the nuclei, is torn away in removing the retina. Immediately outside the retinal pigment lies, first, an extremely thin hyaline layer, and next it is the chorio-capillaris. The latter is remarkably rich in vessels of considerable size. External to this again lies the ordinary stroma of the choroid, and midway between its two surfaces run the large arteries and veins. The vasa vorticosa, anterior to their exit through the cartilage, are filled with a coagulum destitute of red corpuscles, instead of the ordinary blood-clot found in the other vessels of the choroid. This coagulum (see fig. 3, *b*^s) in the sections examined is of a greenish colour, and has numerous minute elongated dark granules distributed throughout its thickness. In that part of the vein which lies just within the aperture in the cartilage, the blood-clot contains red corpuscles as elsewhere.

The *ciliary processes* are of large size, and extend from the termination of the cartilage forwards to the corneo-sclerotic junction. There is a little smooth muscular tissue developed

between the anterior part of the choroid and the sclerotic (fig. 1, *f*).

The *iris* forms a very small angle with the periphery of the cornea and is very densely pigmented. Along its anterior surface are a number of large round pigment cells. On account of the abundance of pigment, it was found impossible to determine its intimate structure, further than that there is a fibrous stroma, and that a thickening occurs corresponding to the position of the sphincter pupillæ. No trace of striated muscle-fibre was found such as occurs in birds.

The *lens* is situated far forward, so that the anterior chamber is very shallow. It is biconvex in form, the curvature of the posterior surface being much higher than that of the anterior. In the specimen examined, the anterior peripheral fibres remained attached to the anterior pole, but from this point towards the equator, they were raised from the more deeply lying part of the lens, thus giving rise to the appearance of a shallow cup. This was doubtless produced by the action of the spirit. There is a well-marked capsule, and immediately beneath the anterior half of it we have the usual single layer of nucleated cells. The lens is supported by a suspensory ligament arising from the ciliary region.

Retina and Optic Nerve.—The optic nerve is in most respects like that of other mammals, but is remarkable in having no central artery or vein. Immediately alongside it, large posterior ciliary vessels gain access to the choroid (fig. 2). The nerve pierces the two outer coats of the eyeball, and then spreads out to form the nerve-fibre layer of the retina in the usual manner.

The retina itself is in very good preservation, considering the somewhat rough method employed. The ganglion cells are large, and occur for the most part in a single row, but near the optic nerve entrance they occasionally lie two-deep. The inner molecular layer is thick and large; round or oval spaces are seen at irregular intervals throughout it. Lying in one of these spaces, may often be found a large cell with nucleus and nucleolus, evidently a ganglion cell. The inner nuclear layer contains at least three distinct kinds of nuclei or "granules." One is bipolar, oval, with distinct nucleolus, and occurs for the most part in the middle of the layer. Another form is small, round, and granular,

and can sometimes be seen to be connected with a fibre of Müller. A third form occurs in a single interrupted row in the outermost part of this layer; this granule is of large size, and more or less round in shape, with one, and sometimes two nucleoli. Its connections have not been determined. The internuclear layer is found pierced at intervals by the outer processes of oval inner granules. The outer nuclear layer is thin; its granules are elongated vertically, and generally lie two-deep. The external limiting membrane is distinct. The bacillary layer is well-developed, consisting of both rods and cones. The outer segments of the cones are long and tapering. It was just possible to see oil-globules at the outer ends of the inner segments of the cones in teased preparations. These were all of a light greenish colour, but doubtless when in the fresh condition they are of different hues, as described by Hoffmann in the Marsupialia. The outer ends of the outer segments are always found imbedded in the inner part of the pigment epithelium, which separates readily from the outer part. This latter part of the pigment remains generally adherent to the inner surface of the choroid as mentioned previously. When it is removed and viewed from the surface, it is found to consist of cells of the usual hexagonal shape. The fibres of Müller are very distinct, and can be traced well through the inner nuclear layer. No blood-vessels occur in any part of the retina, and none were found in the vitreous chamber; it would seem to be nourished from the rich chorio-capillaris.

TABLE OF MEASUREMENTS (in Millimetres).

Transverse diameter of the eyeball,	6.
Greatest thickness of sclerotic, choroid, and retina together, .	0.7
" " cartilage (posteriorly),	0.4
Average " " (in equatorial region), .	0.15
Least " " (at anterior rim),	0.025
Thickness of the fibrous sclerotic in front of the cartilage, .	0.15
Thickness of cornea in the centre,	0.055
" " at the periphery,	0.1
Distance from the middle of the posterior surface of the cornea to the front of the lens, about	0.3
Antero-posterior diameter of the lens,	1.75
Transverse " " 	2.45
Greatest thickness of the ciliary muscle, about	0.1

Fig. 2. Antero-posterior section through the posterior part of the eyeball, a little to one side of the optic nerve. The opening in the cartilage through which the nerve enters the globe is seen. *a*, Retina; *b*, choroid; *c*, cartilage and its fibrous covering. In the aperture in the cartilage, surrounded by fibrous tissue, two large posterior ciliary arteries are shown cut across (*d*, *d'*). By the side of *d'* is a section of a large nerve.

Fig. 3. Section through the outer coats of the eyeball a little posterior to the ciliary region. *a*, *a'*, Pigment epithelium. The outer part (*a*) adheres to the choroid, while the inner part (*a'*) is generally torn away with the retina. Part of the retina was in position, but is not shown. *b*, Choroid. The hyaline membrane is extremely thin, and was not visible in this section. *b*¹, Chorio-capillaris; *b*², *b*², pigmented stroma of choroid, containing large vessels; *b*³, an anterior branch of one of the vasa vorticosa;—it is filled by a coagulum devoid of corpuscles, but studded with small dark granules. *c*, Hyaline cartilage; the larger cells are in the middle; *d*, *d'*, the fibrous tissue on each surface of the cartilage. The outer fibrous covering is here of considerable thickness.

Fig. 4. Vertical section through the retina, not far from the optic nerve-entrance. *a*, Nerve-fibre layer. *b*, Ganglion-cell layer. The cells are placed between the rods of Müller. *c*, Inner molecular layer. Spaces are shown at intervals, two of them occupied by ganglion cells. *d*, Inner nuclear layer. At least three distinct kinds of inner granules or nuclei are represented. *e*, Internuclear layer, pierced at one or two points of processes from bipolar inner granules. *f*, Outer nuclear layer. *g*, External limiting membrane. *h*, Bacillary layer. *i*, Pigment-epithelium; showing an outer dark thick even layer, which generally adheres to the choroid, and an inner granular part containing the nuclei. *k*, Rod of Müller.

ON THE NATURE AND ACTION OF CERTAIN LIGAMENTS. By D'ARCY W. THOMPSON, B.A., *Trinity College, Cambridge.*

THE ligaments cited by Mr J. B. Sutton in the April number of this *Journal* (p. 225, 1884), which appear to be the detached tendons of muscles or degradations of muscles themselves, are almost all ordinary ligaments with the natural functions commonly ascribed to such structures. But there is another class of ligaments which are much more evidently degenerate muscles, and whose remarkable feature is that they continue to perform the function of the muscle they represent. These ligaments are all developed from muscles which pass over two joints ("zweigelenkige Muskeln"), which muscles, as is well known, have a certain amount of passive or automatic action quite apart from their contractile power. I have no intention of discussing Mr Sutton's examples; but, in the case of muscles which pass over two joints, the tendency to degenerate into ligament is natural, and the process may be seen going on.

The limbs of the mole and the horse afford the best instance I know of the active function of ligaments, while the bird's wing presents an interesting intermediate stage.

The muscles and tendons of the mole's fore-arm are not of themselves remarkably strong, considering the work that the limb has to do; the tendons of the flexores carpi radialis and ulnaris are extremely thin and the muscular bellies not particularly large, while many of the smaller muscles are quite rudimentary. But in front of the fore-arm lies an enormous ligament, thicker than the ulna itself, which divides in the palm to be inserted into the five digits, and is attached above to a depression just in front of the internal supra-condyloid ridge and process of the humerus. It represents, in fact, the flexor sublimis metamorphosed into ligament. Beneath it the small fleshy belly of the flexor profundus remains, but the tendons of the latter muscle are fused with the great ligament. It is by

means of this ligamentous flexor that the fingers are flexed in digging, for the movements of the *elbow-joint* are sufficient to tighten the ligament, and so to flex the fingers automatically. And this happens in two ways. In the first place, the inner supra-condyloid process to which the ligament is attached is so long that it acts as a short lever arm, and by its means, when the fore-arm is flexed directly upon the arm the ligament is rendered tense. But the whole range of motion of the fore-arm in direct flexion is not great in the natural condition of the parts, and a movement of *rotation* at the elbow-joint is of far more importance. For when the foot comes to the ground the plane of the flattened humerus is almost vertical and the radius and the ligament are parallel, and the latter lies at some distance below the former. The humerus is so suspended at both ends, that is to say, at the elbow and at its scapular and coraco-clavicular attachments, that it can be made to rotate about its own long axis by the muscles attached in or near its inner (or in the position described, *inferior*) edge. The pectoralis major and the enormously developed teres major, in drawing back the limb, give the humerus this rotation when the digits encounter the resistance of the ground, a fulcrum being supplied by the scapular and coraco-clavicular articulation. Before rotation takes place, the inner supra-condylar process with the origin of the ligament is well in front of the head of the radius; after rotation is completed it is considerably behind, and so this rotation of the humerus, effected by the great muscles of the breast and shoulder, flexes the digits automatically and most powerfully. Professor Macalister tells me that a similar ligamentous mechanism exists in the three-toed sloth. I know of no case save the mole in which this peculiar extensive *rotation* of the humerus takes place. The extreme breadth of the inferior extremity of the humerus, compared with the narrow articular surface of the ulna, gives a powerful leverage in this action.

In the bird's wing the extensor carpi radialis longior acts in a somewhat similar manner. The muscle retains its fleshy belly, but it is small and to some extent tendinous throughout. Since the elbow-joint and wrist of a bird flex in opposite directions, the muscle is not long enough to admit of the elbow being extended while the wrist is flexed;

so that when the fore-arm is extended by the triceps the wrist and hand are automatically extended also. In the folding up of the wing the flexor carpi ulnaris plays an exactly similar but converse part; it is likewise in great part tendinous, and as the elbow is flexed it automatically flexes the wrist-joint also. Both of these muscles, therefore, have mainly a ligamentous action, supplemented, however, by a small range of contractility; and although I know no case in which the muscles have become purely ligamentous, it is indisputable that the stronger the wing and the greater the bird's power of flight the weaker are these muscles, and the longer are their tendons in proportion to the fleshy bellies. Thus the muscles are less powerful and the tendons more extensive in the swift and the kestrel than in the thrush. It is well known, by the way, that an automatic action of this kind is partly effected by the bones of the fore-arm; for, the radius and ulna being placed parallel and one almost superior to the other, the radius is drawn back by the humerus as the latter is extended upon the ulna, and the radius then has a slight extensor action on the wrist just as the extensor radialis has been shown to have. And it is interesting to find that in the mole, too, the bones take an identically similar share in the automatic mechanism. For here again the ulna and radius are parallel and in the plane of the direction of motion at the wrist-joint. They work on one another just as the bars of a parallel ruler do; and when the humerus rotates in the manner described above, the radius is pushed forward and tends to flex and press down the wrist, while in the return stroke the converse occurs.

The last instance that I shall take is the suspensory ligament of the horse, which Mr J. B. Sutton himself mentions. The fact that this ligament supplies the place of muscles has often been remarked, as for instance by Stubbs in 1766; but Professor Cunningham has shown clearly that it is just a fibrous representative of the short flexor of the digit. In the ruminants it represents the two short flexors of the third and fourth digits. Now, as to its action. The common statement concerning it is that it prevents over-extension of the fetlock-joint. Cunningham says (*Nature*, September 29, 1881):—"It plays an important part in the mechanism of the limb. Its attachments are such that it prevents over-extension at the fetlock or metatarso-

phalangeal joint, and its value in this respect is evidenced by the fact that when it is ruptured the horse becomes what is termed by veterinary surgeons 'broken down.' But it has more than this mere passive purpose; it has an active function comparable to that of the other ligaments already discussed. It in fact retains part of the function as well as the position of the short flexor muscle. Firmly attached above to the head of the large metacarpal bone (taking the fore-foot), and continuous there with the posterior common carpal ligament, it is inserted below by two heads into the sesamoid bones; and thence the ligamentous mechanism is continued on—firstly, by bands going to fuse with the extensor tendon on the dorsum of the foot, and, secondly, by strong ligaments inserted dorsally into the second phalanx or coronet bone. These latter, together with the suspensory ligament, are the chief agents of leverage power from the 'knee' downwards. They become tense and strained as the limb rotates, and as the cannon bone reaches its maximum extension they initiate the flexure of the toe; and it is only secondarily or subsequently that the comparatively weak flexor muscles of the digit come into play.¹

I hold it to be a general rule that when a muscle, by reason of its passing over two joints, is capable of being replaced partly or wholly by a ligament, without its efficiency being lost, then ligamentous change will set in. It is not, as Cunningham would have it, that when the muscle is no longer needed it degenerates into ligament, but, on the contrary, when its action is needed most frequently and forcibly. Then, if the mechanical structure of the part permits, the muscle becomes metamorphosed into a ligament to which it hands over its old functions, and the energy is supplied by muscular tissue massed on or near to the trunk. The fingers of a mole are flexed by the pectoralis and teres major, the bird's wrist is extended by the triceps, and in the horse the action of the muscles inserted into the pisiform, or the os calcis, is continued by ligaments to the toes. By this means muscular tissue is economised, and the weight of the extremities is reduced.

¹ I believe the first account of the active function of ligaments was given by Mr Joseph Gamgee in a paper "On the Physiology of Action in the Horse."—*Edinburgh Veterinary Review*, 1862, and elsewhere in the same journal.

It would be interesting to study the action of the limb in some Cetacean. Mr J. B. Sutton quotes from Professor Struthers concerning the narwhal, that the muscles of the fore-arm are "histologically represented throughout by *fibrous tissue*, and *functionally they are ligaments*." I am inclined to think that the latter part of this statement may deserve modification.

Professor Macalister suggests to me that the very broad humerus of the seal may have something of the same *rotatory* action that I have described in the mole.

a

EXPLANATION OF FIGURES.

Fig. 1. Mole's left fore-limb in position of extension. *l*, Flexor ligament; *a, b*, axis of rotation of humerus.

Fig. 2. Limb not quite fully flexed. *r*, Radius; *u*, ulna; *pm*, direction of pull of pectoralis; *c, d*, direction of rotation of humerus; *sc*, scapula; *e*, flexor ligament.

RESEARCHES INTO THE HISTOLOGY OF THE
CENTRAL GREY SUBSTANCE OF THE SPINAL
CORD, MEDULLA OBLONGATA, AND PONS VAR-
OLII. By W. AINSLIE HOLLIS, M.D. Cantab., *Brighton*.
Part IV. (PLATE XX.)

(Continued from page 206.)

IN the foregoing papers on this subject (*Journal of Anatomy*, XVII. and XVIII.) I have attempted to describe the grey synectic tissue surrounding the rachidian canal. At the nib of the calamus scriptorius, this tube expands by a funnel-shaped opening into the cavity of the fourth ventricle. A sectional view of the canalicular orifice (Plate XX. fig. 1) displays the relative positions occupied by the adjacent grey ganglia. A full description of these nervous masses will be out of place here. I shall, however, draw attention to certain peculiarities in their arrangement, as they may assist us hereafter in solving some of the problems associated with this most important part of the nervous system.

At the cephalic extremity of the canal the clavæ, which have previously assisted in forming its posterior wall, pass outwards, leaving a space to be filled with a pad of loose synectic tissue, separated by numerous pia matral septa, and termed in text-books the "bolt" commissure (obex, riegel of Meynert, &c., figs. 1, 2, *ob*); this commissure extends about a line down the canal. The lateral boundaries of the infundibulum above described (fig. 1, *ac*, *ec*), are the ganglia, named the alæ cinerææ, with their eminences. These ganglionic tracks of grey substance can be traced downwards uninterruptedly as the limiting tissue of the canal nearly to the pyramidal decussation. The wedge-like form assumed by the synectic tissue hereabouts is well shown in a transverse section through the medulla, just below the lower ends of the funiculi teretes (fig. 3, *ac*). From this point upwards to the calamus the central grey substance is separated from the surrounding tissues by pia matral septa, containing numerous

blood-vessels, and showing still more clearly than heretofore the disconnection between this central grey column and the surrounding tissues (fig. 3, *p*; fig. 2, *p*). At the anterior and outer aspect on either side, the grey synectic tissue (*i.e.*, the *alæ cinereæ*) separates for the passage of a bundle of nerve fibres, and so forms an oval opening (*ib. fs*). The position of this opening and its contained bundle of nerve fibres necessarily changes with that of the *ala* to which it is connected, passing outwards in its cephalic course, as the grey ganglia become more widely separated from each other (*cf.* figs. 3, 4, 5, *fs*) by the interpolation centrally of the *funiculi teretes*. Krause has traced the bundle of nerve fibres contained in the oval opening above alluded to (*funiculus solitarius, f. respiratorius*) as far as the origin of the phrenic nerve in the cord. I have been unable to do so. At all events it is certain that this defined cylinder of grey synectic tissue terminates at a higher point than that mentioned. It is hazardous to trace any special series of nerve fibres subsequently in its passage downwards to the cord.

At the anterior aspect of the medulla, near the point of pyramidal decussation, the involutions of the pia mater are very deep, and in many cases pass into the central grey substance, making the canalicular walls thin (fig. 6, *vv*). These pia matral septa would appear to mark the lowest point attained by the prolongation of the grey substance of the floor of the fourth ventricle. I believe that in this anatomical disposition of the pia mater we have a further confirmation of the view that the *alæ cinereæ* extend along the canalicular walls to this point (*cf.* Plate IV. fig. 4). If a bilateral longitudinal section of the medulla is examined, we shall find the central grey investing column of the canal at its upper extremity (fig. 7, *b*) is separated from the perforated tissue of the arcuate fibres by a series of pia matral implications, containing small blood-vessels. The surrounding fibrillæ take, at the same time, a direction from without inwards and downwards (*ibid.*, *aa*). From whatever point of view it is taken, the middle medulla represents a central, more or less consistent, grey synectic tissue cylinder, surrounded by a border of looser reticular tissue, containing nerve fibres and blood-vessels in the interspaces. If we accept the view that this central cylinder is actually a prolongation of the ganglionic floor

of the fourth ventricle, as far, and only so far, as the point of decussation of the anterior pyramids, we shall expect to find some cause for this peculiar arrangement. I believe embryology will assist us at this point of our inquiry. The medulla is developed from the lower division of the third primitive cephalic vesicle (metencephalon); the cerebellum, on the other hand (the keystone of the ventricular arch at this part), and the pons (the floor of the same), originate in the upper division of the same vesicle (epencephalon). It would seem that in the course of development the lower vesicular division overlaps the upper, and hence arises the peculiar arrangement of the grey substance I have described.

For a short distance downwards the funiculi teretes form the anterior boundary of the canal. Below this point, as I have before stated, the *alæ cinereæ*, with their eminences, enclose the canal on all sides.

The Raphé.—The lower medulla may therefore be roughly considered to consist of a bilateral aggregation of nerve fibres and ganglia, pierced by a central grey synectic cylinder. Each lateral half is divided, moreover, longitudinally by a series of curved septa of the same tissue (arciform fibres) arranged concentrically, and amalgamated in front into a stout wall of grey substance, placed vertically in man, and called the *raphé*. This septum is thereby closely connected with the grey synectic tissue of the restiform body (fig. 5, *af*) at its upper extremity. Lower down synectic bands pass between it and the lateral nuclei (the remainder of the anterior spinal horns), the nuclei graciles and n. cuneati (fig. 6, *af*); on the other hand, its relations with the central cylindrical extension of the *alæ cinereæ* and the ventricular floor are less intimate. At a level with the base of the olivary bodies the *raphé* is only attached to the centrum by an extremely narrow band of synectic tissue posteriorly; and although this connecting band is somewhat broader as it passes upwards, I think we must consider the *raphé* as essentially made up of fibres, associating the postero-lateral ganglia of the medulla with each other and with the proper grey substance of the cord, rather than with the grey centrum of the upper medulla and pons Varolii (fig. 6, *r'*). Throughout the greater part of its length the *raphé* has a series of blood-vessels

traversing at intervals its vertical walls on either side (fig. 8, *vvv*).

The Obex and the Ligula.—The two pads of loose synectic tissue with numerous included septa of pia mater, together forming the “bolt,” can be traced for some distance along the canalicular parietes, as the former are interposed between the grey prolongation of the alæ and the corresponding nucleus gracilis. The tissues composing the *obex* are intimately connected anteriorly with the synectic tissue of the grey centrum. In the very young these relations can be readily traced. At a higher level the posterior wall of the fourth ventricle is composed of a narrow band of synectic tissue covered with epithelium, and called the ligula. This layer of mostly grey substance is closely connected with the obex on the one hand, and with tuberculum acusticum on the other. It passes over the most prominent portion of the latter nucleus until the striæ acusticæ are nearly reached, it then turns outwards to the lateral recess of the ventricle on either side. In many text-books the ligula is said to be attached along the inner edge of the corresponding restiform body. This statement is incorrect. It really has no direct connection with this body anywhere along its course, as may be seen in the accompanying figures (figs. 4 and 5, *lg*).

EXPLANATION OF PLATE XX.

Fig. 1. Longitudinal section through the cephalic end of the canal. (Parts in section shaded with transverse lines.) *ft*, Funiculus teres; *ec*, eminentia cinerea; *ac*, ala cinerea; *ob*, obex “bolt” commissure; *cl*, clava. Adult.

Fig. 2. Transverse section through the grey centrum of the medulla somewhat below the calamus. *cl*, clava; *p*, pia matral septum; *ob*, obex; *c*, canal; *h*, hypoglossal nucleus.

Fig. 3. Transverse section through the grey centrum medullæ, close to the canalicular orifice; *ac*, ala cinerea; *p*, pia matral septum; *ng*, nucleus gracilis of clava; *fs*, funiculus solitarius.

Fig. 4. Transverse section of the grey medullary centre on a level with the middle of the funiculi teretes. *ft*, Funiculus teres; *ac*, ala cinerea; *ta*, tuberculum acusticum; *lg*, ligula; *cl*, clava; *fs*, funiculus solitarius. Man.

Fig. 5. Transverse section of the grey medullary centre on a level with the upper termination of the ala cinerea. The letters refer mostly

to similar parts in the preceding figure. *cr*, Corpus restiforme; *af*, arcuate septal (fibres) passing from the restiform body to the raphé. Adult.

Fig. 6. Transverse section of the medullary centrum of a kitten, five days old. *c*, Canal; *r'r''*, raphé; *lp*, lateral nucleus; *af*, connecting bands between lateral nucleus and raphé; *vv*, vessels.

Fig. 7. Bilateral longitudinal section of medulla near the cephalic extremity. Youth, aged about 18. *aa*, Arcuate fibres; *b*, column of motor ganglia containing * * vessels; *d*, synectic tissue immediately surrounding (*c*) canal.

Fig. 8. Bilateral longitudinal section of the raphé of the same youth as above. *vvv*, Vessels arranged on either side of the septum passing transversely along its walls.

VARIATIONS OF THE THORACIC DUCT ASSOCIATED
WITH ABNORMAL ARTERIAL DISTRIBUTION.
By ARTHUR THOMSON, M.B., M.R.C.S., *Senior Demonstrator
of Anatomy, University of Edinburgh.*

THE variations of the thoracic duct are so numerous, and the instances on record in which it has deviated from the so-called normal condition, so frequent, that many attempts have been made to classify these conditions. Thus Lane¹ tabulates the varieties as follows:—

- I. A double duct, one terminating in the left, the other in the right side of the neck.
- II. A bifurcation of the duct at a higher or lower level, one branch terminating in the angle of union of the subclavian and internal jugular veins of the left side, the other emptying itself either into the corresponding point on the right side, or joining the right lymphatic duct close to its termination.
- III. A single trunk terminating altogether on the right side at the conflux of the internal jugular and subclavian veins, in which case a short lymphatic trunk is found on the left side similar to that which usually exists on the right.

In connection with the latter division, Morrison Watson² has proposed a further subdivision into—

- (a) Those conditions in which the duct passes to the right side unassociated with any vascular peculiarity.
- (b) Those cases in which the duct passes to the right side, and in which there co-exists some vascular peculiarity.

As examples of Class I. of these varieties, we find that Cruickshank³ has recorded an instance of the duct being double

¹ Todd's *Encyclop. Anat. and Phys.*, vol. iii. p. 225.

² *Journal of Anat. and Phys.*, May 1872.

³ *Anat. of Absorb. Vessels*, p. 175.

throughout, its limbs passing to the right and left side of the neck respectively; a similar condition is recorded by Krause.¹

With regard to examples of Class II. it not unfrequently happens that the duct in its course upwards in the thorax is subdivided into two trunks, which are frequently connected by transverse channels; indeed, according to Teichmann,² this is to be regarded as the normal condition, an arrangement in which the two portions of the thoracic duct bear the same relations to each other as do the major and minor azygos veins. Under ordinary circumstances, the divisions of the duct unite opposite the seventh dorsal vertebra, but, as occasionally happens, they remain separate, and terminate on the right and left sides of the neck. Cloquet has observed a condition similar to this, in which the one vessel followed the ordinary course, the other passed to the right side of the neck, and there united with the right lymphatic duct. Nuhn⁴ has recorded a case in which this division of the duct remained permanent; sometimes, however, the separate channels unite as high up as the region of the neck. Patruban⁵ has described a fork-like division of the thoracic duct into two branches, of which one passed to the right subclavian vein, the left termination forming a ring through which the subclavian artery passed.

The examples of Class III., viz., these cases in which a single duct exists which passes to the right, are much less frequent, and, adopting the further subdivision suggested by M. Watson, we find Cruickshank⁶ mentioning an example which occurred in a child, in which there appears to have been no variation in the arterial system. M. Watson⁷ likewise records an instance in which the duct passed to the right side; he was, however, unable to find any duct corresponding to the right lymphatic duct on the left side of the neck.

¹ Quain, 9th ed., vol. i. p. 529.

² "Das Sangadersystem vom anatomischen Standpunkte bearbeitet," Leipzig, 1861 (quoted from Luschka, *Anat. der Brust.*, p. 449).

³ *Traité d'Anatomie*, vol. ii. p. 1008.

⁴ Quoted from Henle's *Gefäßlehre*, p. 426.

⁵ Quoted from Henle's *Gefäßlehre*, p. 425.

⁶ *Anat. of Absorbents*, p. 175.

⁷ *Journal of Anat. and Phys.*, May 1872.

Fyfe¹ cites a similar case, but found a left lymphatic duct.

Under subdivision (b) of Class III., viz., those associated with vascular variation, we find Fleischmann² mentioning a case where the thoracic duct ran behind the arch of the aorta towards the right, and opened into the right subclavian vein through its posterior wall. In this instance the carotid and subclavian arteries of the right and left side took their origin separately from the aorta. Cruickshank³ also notes an example in which the duct passed to the right side, and in which the right subclavian artery arose from the descending portion of the aortic arch; in this case he records also the existence of a left lymphatic duct. Todd⁴ recalls an instance in which he observed the duct opening into the angle between the right internal jugular and right subclavian veins in the body of a child, in whom the right subclavian artery arose from the extreme left portion of the arch of the aorta.

Allen Thomson, in a case quoted by Turner,⁵ describes the peculiarity of the duct joining the angle of union of the right jugular and subclavian veins; in this case there was a complete transposition of the aortic arch from the left to the right side. Macdonald Brown,⁶ more recently, has noted an instance in which the duct passed to the right side of the neck. The origin of the right subclavian being at the same time abnormal from the posterior aspect of the second part of the aortic arch; in this case Brown found a left lymphatic duct, and also observed that the thoracic duct opened into the veins on the right side of the neck, independently of the right lymphatic duct. The three examples I have met with are very similar to that recorded by Brown, and were all associated with a root origin of the right subclavian.

Case I. occurred in an adult female. In the dissection of this subject the right subclavian artery was seen to spring from the posterior surface of the junction of the second with the third portion of the aortic arch; this irregular trunk passed backward,

¹ *Compendium of Anat.*, vol. iii. p. 164.

² *Leichenöffnungen*, p. 237.

³ *Anat. of Absorb.*, p. 208.

⁴ *Cyclop. of Anat. and Phys.*, vol. iii. p. 232.

⁵ "Irregularities of the Large Blood-vessels," *British and Foreign Medico-Chir. Review*, 1862, p. 184.

⁶ *Journal of Anat. and Phys.*, vol. xvi. pt. ii.

and to the right, behind the trachea and œsophagus lying in front of the body of the third dorsal vertebra; it then passed obliquely upwards across the body of the second dorsal vertebra, towards the right side of the body of the first dorsal vertebra. Arching outwards over the apex of the right pleural sac, it acquired its normal position on the upper surface of the first rib. In its course upward the artery lay in close contact with, and to the right side of, the trachea, and was bound down to the anterior aspect of the bodies of the vertebræ by a fascia of considerable density.

The thoracic duct in this case was normal in its course and position as high as the level of the fourth dorsal vertebra. At the level of the seventh dorsal vertebra it was much split and broken up, but these vessels again united and were found as a single trunk opposite the body of the fourth dorsal vertebra. At this point, instead of turning towards the left, it continued its course directly upwards, resting on the anterior aspect of the irregular right subclavian artery, and being retained in that position by its intimate connection with the fascia which ensheathed and bound down the aberrant trunk.

Traced onward, the duct lay alongside and close to the right of the trachea, and was followed on the anterior surface of the artery to the point at which that vessel curved over the apex of the pleura, here the duct came into relation with the subclavian vein internal to the scalenus anticus and first rib, and opened into the posterior and inferior aspect of that vessel. As the duct lay in front of the subclavian artery, it had anterior to it, in that part of its course which lay between the second and third dorsal vertebræ, the common carotid artery of the right side, which occupied the position normally held by the innominate artery. On the right side it was noticed that the pneumogastric passed obliquely across the bodies of the first and second dorsal vertebræ behind the trachea, and to the left side of the abnormal subclavian artery; it then reached the posterior surface of the œsophagus, passing down with that structure just in front of the origin of the irregular arterial trunk. The recurrent laryngeal branch of this nerve arose in the neck opposite the fifth cervical vertebra, and, passing downwards and inwards in front of the prævertebral region, reached the side of the trachea by passing behind the right common carotid artery.

In Case II. the right subclavian artery arose from the posterior aspect of the second portion of the aortic arch, opposite the lower part of the body and lower border of the second dorsal vertebra; it then passed obliquely upward and to the right, lying behind the œsophagus and trachea, and resting on the anterior aspect of the bodies of the second and first dorsal vertebræ, until it lay on the head of the first rib at its articulation with the first dorsal vertebra; to these structures it was firmly attached by surrounding fascia. Opposite the head of the first rib the right subclavian gave off the vertebral artery, then, passing outwards over the pleura, it reached the arterial groove on the first rib.

In this instance the thoracic duct lay in its normal position as high as the body of the third dorsal vertebra. Here the duct lay behind the œsophagus and behind the third part of the aortic arch, then, meeting with the irregular origin of the right subclavian, it appeared as if diverted from its ordinary course, and turning to the right lay at first along the lower border of the irregular trunk, and then obliquely crossed its anterior surface, to terminate somewhere in the region of the junction of the right subclavian with the right internal jugular vein. This point unfortunately could not be satisfactorily cleared up, as the dissectors of the head had removed the veins on that side of the neck.

In this subject the course of the pneumogastric differed somewhat from that recorded in Case I. Here the nerve crossed the subclavian artery, just internal to the origin from it of the vertebral artery, and then, passing obliquely downwards and inwards, it reached the œsophagus. The recurrent laryngeal branch arose at a higher point than that at which the vagus crossed the artery, and curved inwards and downwards on front of the prævertebral region. In neither of the cases was the existence of a left lymphatic or right lymphatic duct demonstrated, as the dissections were too far advanced to admit of these structures being recognised.

My interest in this subject having been aroused by the two cases already mentioned, I was on the outlook for such examples of arterial abnormality, and with this object in view I passed my finger along the course of the right common carotid artery

(at an early stage of the dissection) in a number of bodies, in order to recognise the bifurcation of the innominate. Failing to make this out in the case I am now about to record, I felt sure that this must be a similar example to those already recorded. Anxious to test this, I stated to the students present that it was probable that we should find the thoracic duct opening into the veins on the right side of the neck. By means of a little dissection I was enabled to demonstrate the correctness of my views.

The facts of Case III. are as follows:—

The aberrant subclavian differed in no wise from the instances I have already noted. It arose from the posterior aspect of the descending part of the aortic arch opposite the lower half of the left side of the body of the third dorsal vertebra; it then crossed obliquely from left to right, and from below upwards, on the bodies of the third, second, and first dorsal vertebræ, resting on the neck of the first rib on the right side. As it passed towards the right it had lying on front of it the œsophagus and trachea, and passing down between it and the œsophagus was the right pneumogastric. As the nerve coursed down in this position, it gave off numerous offsets to the plexus gulæ. *In the neck* the relations of the right subclavian artery were normal, with the exception that it had the thoracic duct *passing down on front of it*.

Its branches, however, were irregular. Thus we found a small artery (about the size of one of the divisions of a digital branch) which had the origin, course, and relations of a normal vertebral artery. This branch was accompanied and concealed by a vertebral vein of large size, a small branch from which ran upwards to pass into the foramen in the transverse process of the fourth cervical vertebra, and accompany an artery to be mentioned hereafter.

The thyroid axis was of small size. The inferior thyroid artery being the only branch of normal size, the transversalis colli and humeri were quite diminutive.

Another point of interest in connection with this abnormal arterial distribution was the distribution of the right common carotid. At a point corresponding to the bifurcation of the innominate, just behind the right sterno-clavicular articulation, the right common carotid gave off a branch equal in size to a

normal vertebral artery. This artery passed upwards and outwards in front of the longus colli towards the foramen in the transverse process of the fourth cervical vertebra, which it entered accompanied by the offset from the vertebral vein mentioned above.

Posterior to this artery lay the inferior thyroid artery, and opposite the lower border of the body of the sixth cervical vertebra the recurrent laryngeal nerve passed transversely inwards. Some cardiac nerves also lay behind it.

In front the artery was for a part of its course ensheathed in the common investment of the carotid vessels; in close contact with it above, and to its inner side, lay the right pneumogastric nerve. The nerve then crossed the artery obliquely, and finally lay to its outer side, at which point it gave off its recurrent laryngeal branch, which passed in behind the artery. The internal jugular veins, the sympathetic, the descendens noni, and the fibres of the sterno-mastoid lay superficial to it.

Laterally it had to its inner side the right common carotid, and at a higher level the vagus and descendens noni; externally and below, the internal jugular vein and, at some distance from it, the normal vertebral vein.

The thoracic duct was normal in its relations as high as the level of the upper border of the fourth dorsal vertebra. Here the duct passed obliquely upward and to the left, lying half an inch to the left of the middle line of the body of the third dorsal vertebra; in this position it was *crossed by* the abnormal subclavian, which passed obliquely over it from left to right, and from below upwards, the artery thus lying between the duct and the œsophagus. In this instance, then, the relations of the duct differ from those recorded in Cases I. and II., as in these examples the duct lay on front of the artery—here it lay behind. At the level of the lower border of the second dorsal vertebra it turned to the right, and ran parallel to the course of the right subclavian, and between one-fourth and one-half an inch above the level of the upper border of that trunk. At the point at which the duct bent to the right, it was connected with a lymphatic of considerable size, which, after being traced upwards, and to the left for about one inch, was lost in the fat.

As the duct passed in the direction above described, it lay

on the anterior surface of the longus colli, with the fascia of which it was connected; anterior to it was the œsophagus.

Passing outward and to the right it separated somewhat from the right subclavian, and was crossed by the right common carotid and right pneumogastric. It was then concealed by the right internal jugular vein, and, passing obliquely downward and outward between the right internal jugular vein and right vertebral vein, it *lay across* the first portion of the right subclavian artery, close to the inner border of the scalenus anticus; then, passing for a short distance on to the anterior surface of the scalenus anticus, in which position it lay superficial to the right phrenic nerve, it curved slightly inwards and downwards, and terminated at the receding angle, formed by the junction of the right subclavian and internal jugular veins. Just previous to this point it was joined by a lymphatic of large size, corresponding to the right lymphatic duct.

Though careful search was made, no evidence could be found of the existence on the left side of the neck of a left lymphatic channel.

The sympathetic on the right side of the neck was peculiar, the middle cervical ganglion being represented by a ring of gangliform enlargements, through the centre of which the abnormal vertebral artery passed previous to entering the foramen in the transverse process of the fourth cervical vertebra. The nervous cord was continued downwards into the thorax superficial to the artery.

From the consideration of these facts, it would be interesting to know, if, in every case of origin of the right subclavian from the right aortic root or transposition of the aortic arch, a similar disposition of the thoracic duct existed, as it would lead us to presuppose that the transposition of the duct to the right side had some connection with these arterial anomalies.

Henle¹ in connection with the branching off of one part of the duct to the right side, inclines to the view that there is either an arrest of development or an obliteration of the left trunk, thus indicating that there exists between the thoracic radicles of the right lymphatic duct, and the thoracic radicles of the thoracic duct, a channel of anastomosis, which may become

¹ *Handbuch der Gefäßlehre*, p. 426.

enlarged, were pressure or developmental changes to influence the direction of the flow of the lymph.

As far as I am aware no such anastomosis has yet been demonstrated, though I think we have every reason for supposing that such exists.

In plate xix. of Mascagni's work on the lymphatics, the thoracic duct is figured as receiving a large number of radicles from the right and left thorax, those on the right side passing as high as the right side of the body of the first dorsal vertebra, but I cannot here see any connection delineated between the radicles of the right lymphatic trunk and the ductus thoracicus.

In plates xiii. and xv., the thoracic duct is represented as double nearly throughout its whole length, and in plate xxvii. of the same work, Mascagni figures lymphatics passing from the right side of the neck downwards into the thorax. On the surfaces of the right subclavian and innominate artery, a course we see which corresponds very much to the position of the abnormal thoracic ducts cited in Cases I. and II., I have endeavoured in two instances to inject with mercury the right lymphatic duct from the thoracic duct and *vice versa*, but though the injection was successful in distending the minute radicles of these vessels, I was unable to demonstrate any anastomosis. Still, from the consideration of the cases recorded, the duct appears to pursue its normal course until it reaches the abnormal arterial trunk, at which point it seems to have been turned aside, and then (accepting Henle's view), taking advantage of the lymphatics of the right upper thorax (presumably those figured by Mascagni in plate xxvii.), have been carried to the veins at the right side of the neck. The fact that it may open into these veins independently of the right lymphatic duct, proves nothing, as it by no means follows that the lymphatics derived from the right head and neck, right upper thorax, and right superior extremity, which constitute the right lymphatic duct, should open into the veins as a single trunk; indeed, we know that they not unfrequently have separate orifices.

On the other hand, though little is known with regard to the development of the thoracic duct, still we are aware that the larger lymphatic vessels are associated with the larger arterial trunks, and are doubtless developed in connection with them.

Such being the case, is it not probable that we have a lymph channel developed in connection with each of the primitive aortæ, which, following the developmental changes undergone by the primitive arteries, would undergo atrophy in certain portions of their course? Were such a connection proved to exist between the representatives of the thoracic duct at an early stage of development and these primitive aortæ, I hold that many of the variations of the thoracic duct could be readily explained from a developmental point of view; thus the partial splitting of the duct, and the occasional presence of a duct double throughout and terminating on the right and left sides of the neck, could be readily accounted for. As also in the cases herein recorded, in which the root-like origin of the right subclavian represents the persistence of the right aortic root, and in which the lymph channel associated with that root has not become obliterated as it presumably does under ordinary circumstances, but, like the arterial root, has remained patent at the expense of its fellow of the opposite side, and thus established a continuity between the veins of the right side of the neck and the duct in the thorax. Again, in such a case as that recorded by Allen Thomson, in which we have a complete transposition of the aortic arch, we find that the thoracic duct linked itself with the right aortic arch, which remained persistent, and so passed to the right side of the neck. From the consideration of these facts, I am inclined to think that these variations of the thoracic duct are more readily explained by the theory I have advanced, than by such accidental circumstances as have been suggested by Henle. Until, however, more light is thrown on the development of the thoracic duct, and its relations to the primitive aortæ and aortic arches, this explanation of these variations must remain a mere supposition.

ON THE FERMENTS OR ENZYMES OF THE DIGESTIVE TRACT IN FISHES. By WILLIAM STIRLING, M.D., Sc.D., *Professor of the Institutes of Medicine, University of Aberdeen.*

UP to the present time comparatively few observations have been made upon the digestive processes in fishes, more especially in our common food fishes.

The most important observations on this subject are those of Krukenberg.¹

At the request of the Scientific Investigation Committee of the Fishery Board for Scotland, I undertook some observations upon this and allied subjects. A full statement of the results obtained will appear in the Annual Report of the Fishery Board for Scotland.

These observations were made upon fishes caught between the months of January and May of this year, both inclusive. In experiments of this description it is necessary to have absolutely fresh material, but owing to a variety of circumstances this was not always to be had. The following communication is to be regarded merely as a preliminary statement.

METHODS.

The methods I employed were those in use for the extraction of the ferments present in the mammalian digestive tract. One of the best solvents of these bodies is glycerine, and this I used extensively for extracting such ferments as are soluble in it. Besides this I also extracted the mucous membrane with watery fluids which remove the reserved stock of the ferment, or at least the mother-substance of the ferment stored up within the cells which manufacture the ferments. I also subjected some parts of the intestinal tract to the action of the fluid recommended by Dr William Roberts,² viz., a *boracic solution*, which contains 3 to 4 per

¹ *Untersuchungen a. d. phys. Inst. d. Universität, Heidelberg* (W. Kühne), vol. i. p. 329.

² *On the Digestive Ferments*, Wm. Roberts, M.D., 1880.

cent. of a mixture of boracic acid and one part of borax, *dilute spirit*, i.e., water containing 10 to 12 per cent. of rectified spirit, *chloroform water*, which consists of chloroform and water in the proportion of about 1 in 200. The advantage of using glycerine and these other "extracting reagents" is that a solution of the ferments is obtained which can be kept for a length of time and still retain its digestive power. In order to extract the ferments, the mucous membrane of the part to be investigated was first carefully freed from all impurities or traces of food. It was afterwards minced very fine on a glass plate, and then subjected for many hours or days to the action of the solvent. In the case of glycerine, it seemed to me that a more powerful extract was obtained more rapidly by bringing the glycerine into contact with the chopped-up mucous membrane in its perfectly fresh state, than when the mucous membrane was subjected to the action of absolute alcohol for twenty-four hours previously, as recommended by v. Wittich.

After the solvent had extracted the ferment, the solution so obtained was filtered in order to get a clear fluid to work with.

Having obtained a clear solution of the ferment, the next thing was to test its activity upon some substances. As is usual with experiments on artificial digestion, the ferment has to be diluted with an acid or alkaline medium as the case may be. In the case of the extract of the crop and stomach I used a solution of hydrochloric acid (2 parts of the acid in 1000 parts of water), and for the extract of the pyloric appendages I used a 1 per cent. solution of sodium carbonate.

A flake of well-washed fibrin was placed in a test-tube containing a solution of the ferment, and the mixture was exposed to a temperature of 37–40° C. After numerous experiments I found that the ferments of fishes like those of mammals are most active at this temperature, although under normal conditions they act at a much lower temperature. This observation agrees with that of Krukenberg,¹ who found that a temperature of 37–40° C. was as a general rule most favourable for these experiments.

In all cases control experiments were made by previously

¹ *Untersuchungen aus dem physiologischen Institut d. Universität, Heidelberg* (W. Kühne), vol. i. p. 329.

boiling the solution of the ferment, which has the effect of destroying the ferments, so that in these experiments no effect was produced upon the fibrin.

The presence of a diastatic ferment was tested for in the usual way with a solution of starch, and after the mixture had been exposed for some time to a temperature of 37–40° C. the presence or absence of sugar was ascertained by boiling with Fehling's solution. Control experiments were also made in each case by boiling the solution supposed to contain the ferment, and testing the ferment fluid itself. There is one point in testing for the presence of minute traces of sugar which is of importance, viz., to add only a small amount of Fehling's solution, in fact, the mixture should just show the faintest tinge of blue. A trace of sugar may thus be detected, which would not be discernible if too much Fehling is added.

THE HERRING.

The herring used were as "fresh" as could be obtained, were caught off the Aberdeenshire coast, and were in-shore or "rock" herring. All of them contained ripe or nearly ripe milt or roe as the case might be.

The intestinal tract of the herring is peculiar, and is described and figured by Cuvier and Valenciennes,¹ Owen,² and Huxley.³ The best general description is given by Professor Huxley, in his lecture delivered at the National Fishery Exhibition held at Norwich in 1881.

An opening leads from the back part of the mouth between the gill rakers into the gullet, which "passes back into a curious conical sac, which is commonly termed the stomach, but which has more the character of a crop."

This conical sac is continued downwards into a long narrow funnel-like duct, which curves backwards upon itself and opens into the middle of the air bladder. This is the "pneumatic duct."

"Coming off from the under side (near its upper end) of the sac, and communicating with it by a narrow aperture, there is an

¹ *Histoire naturelle des Poissons*, vol. xx.

² *Anatomy of Vertebrates*, vol. i. p. 20.

³ *Nature*, 1881.

elongated tubular organ, the walls of which are so thick and muscular that it might almost be compared to a gizzard. It is directed forwards, and opens by a narrow prominent aperture into the intestine, which runs straight back to the vent. Attached to the commencement of the intestine there is a score or more of larger and shorter tubular organs, which are called the pyloric cæca. They open into the intestine, and their apertures may be seen on one side of it, occupying an oval space in the middle of which they are arranged three in a row."

The long tubular organ referred to by Professor Huxley, under the name of "crop," has a very characteristic structure. Its mucous membrane contains a large number of compound tubular glands, several gland tubes usually opening into a single crypt or depression of the mucous surface. These crypts practically serve as the ducts for the secretory tubular portions of the glands. Each crypt, as well as the surface of the mucous membrane, is lined by a layer of tall columnar epithelium, while the secretory parts of the gland tubes are lined by a single layer of polygonal or cubical cells, often arranged in a somewhat imbricate manner. The cells are large and granular, presenting many of the characters of the *outer* cells in the gastric glands of mammals. No inner cells are present in these glands. In all respects the glands resemble those of the mammalian stomach, except that the inner cells are absent. This tubular organ may be compared with the cardiac portion of the mammalian stomach, and the term "cardiac sac" might be given to it. The part described as a gizzard-like organ by Professor Huxley has crypts of various shapes, lined throughout by the same kind of epithelium which lines the general surface of the stomach. It corresponds in structure to the pyloric end of the stomach, and might therefore be termed the "pyloric sac."

I made an extract of the "*cardiac sac*" ("crop") by means of glycerine, dilute spirit, chloroform water, and a solution of hydrochloric acid (2 per 1000). In all cases a strongly "peptic" extract was obtained. In the case of the glycerine extract, the peptic action on fibrin was obtained whether the mucous membrane of the crop was or was not previously treated with alcohol. A flake of fibrin, placed in a mixture of hydrochloric acid (2 in 1000) along with a proper amount of any of the

above extracts, is rapidly dissolved at a temperature of 37–40° C., and much more slowly at the ordinary temperature of the room. When the solution of the enzym is boiled no digestion takes place. As far as my experiments go, I think the spirit extract is more powerful than that obtained by chloroform.

Instead of using fibrin as the proteid for testing the peptic action of the extract of the cardiac sac, in several cases I washed and neutralised the partially digested contents of the crop of such herring as contained food. These contents, whether crustaceans or sagitta, were also rapidly digested. I made several experiments with other acids, such as lactic (1 per cent.), and a similar result was obtained.

It is therefore quite certain that the mucous membrane of the "cardiac sac" of the herring contains an enzym or ferment, which is active in the presence of an acid medium, and this ferment is pepsin, which in all respects is identical with the pepsin of mammals. Krukenberg has ascertained that pepsin exists in the stomachs of many fishes.

The part of the cardiac sac which lies above the entrance into the *pyloric sac*, or so-called "stomach," when acted upon by similar extracting reagents, also yields pepsin. This is what one would expect from the histological characters of the mucous membrane in this situation.

The *pyloric sac* ("stomach"), when similarly acted upon, yielded an extract with distinct although feebler peptic properties, so that it also contains pepsin. My experiments lead me to believe that the extract of the mucous membrane of the pyloric sac is not so powerful as that obtained from the cardiac sac. I have not made accurate experiments and compared the amount and potency of the ferment (pepsin) obtained from the cardiac and pyloric sacs respectively, but simple digestive experiments show that, other things being equal, the extract of the pyloric sac does not digest fibrin so rapidly as the extract of the cardiac sac.

The Pyloric Appendages.—The uses and homologies of these organs in fishes have for long been a subject of discussion amongst naturalists and physiologists. One point seems quite certain, viz., that they seem to subserve different functions in different fishes. To give a correct exposition of their functions

in any one species would require more extended observations than my opportunities have afforded me. They may be either absorbing or secreting organs, or both. The question as to their absorbing function must rest upon what facilities are afforded to the chyme for entering these organs in the different species, and also upon their structure. In some fishes, as Krukenberg has pointed out, they are purely mucous glands (*Perca fluviatilis*), whilst in others they represent the pancreas, *i.e.*, they contain a "tryptic" ferment (*Clupea sardinia*). Some of the older observers regarded the pyloric appendages as true absorbing organs and nothing more, a view which was partly supported by Rathke,¹ Meckel, and more recently by Edinger,² who however supports his view entirely from histological observations. In some animals, as the cod, the presence of well-marked glands in the walls of these organs is so apparent as to point at once to the view that in these animals at least they are something more than absorbing glands. It is important to remember that the function of secretion does not exclude that of absorption,—both functions may go on simultaneously.

The pyloric appendages of the herring, when extracted with glycerine or a 1 per cent. watery solution of sodium carbonate or spirit solution, yield an extract which has distinct tryptic properties. The glycerine extract rapidly dissolves fibrin in the presence of a 1 per cent. solution of sodium carbonate. In the herring we have evidence of the existence of "trypsin" in the pyloric appendages.

I am led to the belief that the pyloric appendages of the herring also contain a diastatic ferment. In making experiments with the tryptic ferment, one must be careful to prevent putrefaction, and this, as was pointed out by Kühne, is best done by the addition of thymol.

The Bile of the herring is a golden brown fluid with a neutral or faintly alkaline reaction. Like the bile of mammals it contains a diastatic ferment, as shown by its action upon starch. It has no action upon proteids.

The Liver.—The experiments I have made were conducted especially to ascertain the probable amount of sugar contained

¹ *Müller's Archiv*, 1837, p. 354.

² *Archiv f. mik Anat.*, vol. xiii. p. 651.

in this organ, and whether the amount of sugar differed according as the fish was or was not digesting at the moment it was killed. Assuming, as in the case of mammals, that any glycogen present in the liver would be converted into grape sugar, as the fish did not reach me until several hours after their death, on making a watery extract of the liver I naturally expected to obtain abundant evidence of the existence of sugar in the extract. The opposite was the result. In the livers of several herrings so extracted I had great difficulty in convincing myself of the presence of sugar by means of Fehling's test. The livers I used first of all were taken from animals shortly before the period of spawning, and whose stomachs were empty. At first I was inclined to believe that the absence of food from the cardiac sac might explain the traces of sugar in the liver, so I selected the liver of several herrings whose cardiac and pyloric sacs contained food. In this case also I obtained only small quantities of sugar. The relation of the amount of sugars or glycogen in the liver of fishes to the food and other conditions is obviously one deserving of more extended examination, more especially as very variable results were obtained in the cod and skate. The fact that the roe and milt were undergoing such a great development may have influenced the amount of the carbo-hydrates in the liver, as it is a well-established fact that rapidly developing tissues require a large amount of carbo-hydrates. Whether the carbo-hydrates in the liver are or are not influenced by the state of the reproductive organs of the herring, *i.e.*, whether it is in the "matie" stage or in the full condition, when the roe or milt is rapidly enlarging and filling the abdominal cavity, and drawing upon the stored up fatty and other tissues for pabulum to sustain their growth and development, it is quite certain that the fatty accumulations between the muscles and those around the pyloric cæca and about the intestine gradually disappear, and the flesh becomes "poorer." I trust that opportunity will occur during the ensuing season for determining these and other points.

The intestine of the herring has not been subjected to examination, but this I hope to accomplish as soon as opportunity affords.

THE COD.

A glycerine or other extract of the mucous membrane of the *stomach* of the cod is possessed of powerful peptic properties. The gastric glands contain plenty of pepsin, and the reaction of the mucous membrane is distinctly acid. This result is what we would expect. It is no uncommon thing to find fish, such as haddock, in every stage of disintegration in the stomach of the cod. One frequently finds crustacea, molluscs, holothurians, and sometimes great quantities of Aphrodite. The Aphrodite I have found very abundant in the cod's stomach during May. The calcareous coverings of the crustacea and the bones of fishes are rapidly decalcified by the gastric juice. Only the very indigestible portions of the food seem to pass unchanged through the comparatively narrow pylorus into the duodenum.

The *pyloric appendages*, when extracted with glycerine or weak spirit, yield a solution which, in the presence of a 1 per cent. solution of sodium carbonate, has distinct digestive properties, indicating the presence of trypsin. As far as my experiments go, they lead me to believe that the spirit extract is more powerful than that obtained by glycerine. Such an extract acts upon fibrin at the ordinary temperature of a room, but more rapidly at 38° C.

The *bile* has a beautiful green colour, and is obtainable in sufficient quantity for experiments. It is neutral or very feebly alkaline in reaction. It contains a diastatic ferment, but it has no action upon proteids. The diastatic ferment is active in the cold, but more so at a temperature of 37° C. In one case I found that the bile contained a considerable amount of a substance (sugar), which reduced Fehling's solution. In other cases no such substance was found.

The *liver* of the cod, as is well known, contains a large quantity of oily matter in the form of globules in the protoplasm of the hepatic cells. It contains such a large amount of oily matter that it floats in ordinary water. Extracts were made by boiling the liver with water, or with a solution of sodic sulphate.

The results, as regards the presence of glycogen and sugar, varied in different specimens. In one cod's liver, which I examined in this way, in January I found no glycogen, and

with difficulty traces of sugar. This fish had plenty of partially digested food in its stomach.

In two other specimens examined early in May abundant evidence of glycogen was obtained. From a comparatively small piece of liver I obtained a highly opalescent solution of glycogen, after precipitating the proteids by potassio-mercuric iodide, and hydrochloric acid by the method of Brücke. As in the extract of a mammal's liver glycogen is thereafter precipitated by alcohol from the opalescent solution. The same extract showed the presence of a large amount of sugar. In this case the fish was digesting also.

The difference in regard to the extracts of the liver in these two cases was certainly very great, in one no glycogen and mere traces of sugar, in the other plenty of glycogen and sugar, while in both cases the stomach contained food, and in both cases the food consisted of crustaceans and fishes. The one fish was examined in the end of January, when the ova were large, and the others in May, when the reproductive products were shed. Obviously a more extended analysis, as to the food and other conditions, must be made before one can give a satisfactory statement as to the relation of the glycogen and sugar in the liver to the nature of the food, period of digestion, maturation of the reproductive organs, and other conditions.

It is usually stated that the cod is devoid of a *pancreas*, and in the latest work on the dissection of the cod, by T. Jeffrey Parker, no reference is made to this organ. Attached to fundus of the gall-bladder there is a small, more or less oval, white body, resembling a mass of fat, while in the mesentery near it are several other smaller white patches. At first sight they look like fatty matter, but on examination they have a distinctly glandular structure, which resembles that of the mammalian pancreas. The gland acini are lined by cells with an outer and an inner zone, while the inner zone contains granules similar to those occurring in the mammalian pancreas. Other small glandular nodules occur in the mesentery between the loops of the intestine. Structurally they resemble the pancreas. These organs are too small to yield sufficient extract to determine the presence of enzymes within their cells. I reserve a detailed description of these organs until a later period.

THE HADDOCK.

As in the herring and cod, the *stomach* of the haddock contains pepsin, which actively digests fibrin in the presence of dilute hydrochloric acid. I obtained a peptic extract both from the cardiac and pyloric ends of the stomach, the former being the more powerful.

The *pyloric appendages*, like those of the fishes just mentioned, also contain trypsin, while the *bile* contains a diastatic ferment. Not unfrequently the gall-bladder is found empty and contracted. Attached to the gall-bladder is a small organ (*pancreas*) similar to that found in the cod, and which has the same structure as the mammalian pancreas.

THE SKATE.

Its *stomach* yields pepsin—its *bile* contains a diastatic ferment. From the watery extract of the *liver* I obtained a considerable amount of glycogen and abundant evidence of sugar. The skate is specially interesting, as it possesses a well-developed *pancreas*. I have made a number of observations on the structure and functions of the pancreas and organs, which I regard as representing the pancreas in other fishes, but I hope to make this the subject of a special communication at a future period.

NOTES ON THE MINUTE STRUCTURE OF THE SPINAL
CORD OF A HUMAN FŒTUS. By WALTER S. COLMAN,
Student of Medicine, University of Edinburgh. (PLATE
XXI.)

THE following is a short account of some of the appearances presented by transverse sections of the cervical and upper dorsal regions of the spinal cord of a human foetus (about five months). I obtained it twelve hours after expulsion. The spinal cord was at once removed, and hardened in a 2 per cent. solution of bichromate of ammonium for six weeks, methylated spirit being gradually added after the third week, and the hardening was completed in that fluid alone. Sections were made with a Cathcart microtome,¹ and doubly stained, first in eosine (1 in 2000) for half an hour, then in very dilute hæmatoxylin for a quarter of an hour, with most satisfactory results. A few sections were mounted in Farrant, the rest in Canada balsam.

CENTRAL CANAL

The appearance of this canal and the surrounding neuroglia is, in most respects, very similar to the account given by Dr Ainslie Hollis in this *Journal* (vols. xvii. and xviii.), and, in those points in which it differs, seems to indicate an extension, rather than a contradiction, of the views put forth by him there. The canal is lined by a distinct and complete layer of stratified, ciliated, columnar epithelium, forming a deeply-stained ring around the lumen. The superficial cells of this layer are columnar, and contain relatively large, elongated, and deeply-stained nuclei. At the free end of each cell are several cilia, and beneath them a clear hem, in which, in favourable sections, a row of dots may be made out, which seem to be the "basal pieces" of the cilia described by Engelmann. Beneath these superficial cells are numerous smaller angular cells, with large deeply-stained nuclei and very little surrounding protoplasm. These cells, which evidently belong to the epithelium lining the

¹ See description of microtome in this *Journal*, April 1883.

central canal, are arranged in two or three concentric layers, the external cells being smallest and most numerous.

The neuroglia surrounding the canal differs from that in the rest of the grey matter in containing a relatively larger number of cellular elements. The matrix (in these hardened specimens) is coarsely fibrillated, and takes on the eosine staining somewhat deeply, in marked contrast to the neuroglia cells, which are intensely coloured by the hæmatoxylin. These cells are small and rather thickly scattered through the tissue, often in small groups. In form they almost exactly resemble the deeper epithelial cells of the central canal, consisting of an oval nucleus, surrounded by a minute quantity of more delicately-tinted protoplasm.

The question as to the epiblastic or mesoblastic origin of the neuroglia of the brain and spinal cord has for some time been under discussion, and some hold that all the neuroglia is derived from the mesoblast, processes from which enter with the vessels of the pia mater. The appearances of these sections suggest, however, that *all* of the neuroglia is not developed in this manner. The epithelial layer of the central canal derived from the epiblast can be readily differentiated from the surrounding connective tissue, except at one or two points. Here, however, there is an important difference. At these points in the circumference, which vary in position at different levels of the cord, there are groups of eight to ten neuroglia cells in intimate relation with the epithelial layer, and they appear structurally identical with its deeper cells. So close is the relation, indeed, between these two sets of cells, that it seems impossible definitely to differentiate the epithelial from the connective tissue cellular elements. It seems, then, extremely probable that the epithelial cells may be the progenitors of these neuroglia cells, or, in other words, that some at least of the neuroglia cells may be derived from the epiblast.

GREY MATTER OF THE SPINAL CORD.

a. Neuroglia.

The neuroglia is coarsely reticulated and deeply stained, and exactly resembles that already described in connection with the central canal, with which it is directly continuous.

b. Nerve Cells.

(1) *Grouping.*—The groups of cells occupy the same position in the cornua, and have much the same relation to each other as in the adult condition.

The antero-internal group consists of eight to twelve cells, usually compactly arranged.

The antero-external group contains rather more cells, which are larger than the former, and are connected by a distinct path of nerve fibres with the outer fasciculus of the anterior nerve root, and with the antero-internal group of the same side.

The intermedio-lateral group here possesses a larger number of cells than either of the former groups. It has evident connections with the anterior nerve roots, some fibres of which pass through it to the lateral columns of the cord.

Clarke's column is represented in the upper dorsal and the cervical regions by a few scattered cells, which increase in number in the cervical region as we pass upwards.

The grey gelatinous substance of Rolando is well developed, but contains very few nerve cells.

(2) *Direct Anastomoses of Nerve Cells.*—The preparations showed the processes of the nerve cells with extreme distinctness for so great a distance, that a careful search was made for anastomoses between the cells, with the result that some seven demonstrations of this condition were obtained, sketches of four of which are given (figs. 2–5). Examples of cells between which this communication existed were found in each of the tracts of the anterior and lateral cornua. The sections were searched under a power of about 300 diameters, but the appearances were in all cases confirmed by a Zeiss's lens, magnifying 500 diameters. The cells were connected by a fine fibre, the continuity of which was carefully traced throughout its entire extent. Special pains were taken to see that the apparently continuous fibre was not due to the very oblique crossing of two independent processes, and also to make sure that the process from one cell was actually continuous with a process from another, and that it did not merely pass underneath the cell. At each end the fibre was connected to a cell by a distinct thickened process, which was brought into prominence by the eosine staining.

It will be observed that two of the cells figured have two

nuclei (figs. 2 and 4). These were the only two of the series which presented this condition, but it is certainly a possibility that the communication might be the result of the division of a nerve cell, the two daughter cells remaining in connection for only a short time. In fig. 3, however, the cells are both of full size, but the fibre connecting them is remarkably distinct and shows no sign of disappearance; but, obviously to render the point certain, observations will require to be made on spinal cords at a later stage of development.

(3) *Shape of Cells*.—The cells have much the same shape and grouping as in the adult, although the cells of the intermedio-lateral tract are relatively larger, and, as before mentioned, more numerous than they are at later periods of development. Each cell contains a large spherical or somewhat oval nucleus, containing one or not infrequently two nucleoli. Several cells in the anterior cornu contain two nuclei. The intranuclear network is coarse and very distinct. The nucleus is in almost all cases placed eccentrically, usually lying in close proximity to the wall of the cell.

The cell processes vary greatly in form; in some cells they are thick, and do not branch for some distance from the body of the cell, in others they are fine, and branch at once.

In the anterior and lateral cornua nerve cells are to be found, exhibiting every transition of shape from a beautifully regular stellate cell to fusiform and pyramidal cells; but there is nothing sufficiently characteristic to distinguish the cells of one group from those of another.

The cells in the position of Clarke's column are of moderate size, and are pyramidal or fusiform.

Those in the grey gelatinous substance of Rolando are few in number, are fairly large, and pyramidal in shape.

There are numerous large capillary loops in the grey matter.

COURSE OF ANTERIOR NERVE ROOTS.

The *anterior nerve roots* entered by three fasciculi. Of these the outer arched directly outwards to the antero-external group of its own side, the middle interlaced with a set of fibres which emerged from the antero-internal tract, and the two formed a

very distinct band of fibres, which passed backwards to the corresponding intermedio-lateral column. Just before reaching the group, however, the band of fibres divided into two portions, one apparently terminating in the ganglion group, the other sweeping round its inner side to become lost in the posterior cornu. The inner fasciculus passed to the antero-internal group. Many of the bundles of fibres passed through it, and, coursing backwards, divided into two, one part continuing its backward course as far as the position of Clarke's column, where it became lost, the other passing across the anterior commissure, where most of the fibres ran forwards to the antero-internal group of the opposite side.

Posterior Nerve Roots (as seen in transverse sections).—Most of the fibres swept round the grey substance of Rolando, and became almost immediately lost in the white columns. A few passed through the substance of Rolando, and coursed forwards to the posterior commissure, where they were lost.

COMMISSURES.

Owing to the large number of neuroglia cells present in both commissures, it was impossible to differentiate them into white and grey. Each contained a large number of non-medullated and a few medullated fibres and there were also one or two longitudinal medullated fibres transversely divided.

From the bottom of both the anterior and posterior median fissures a band of fibres passed towards the central canal, and, just before reaching it, divided into two bands which swept round the canal. These probably belonged to the connective tissue, as no fibres could be found passing from them to the cornua. They are seen in fig. 1.

WHITE MATTER OF THE CORD.

This contained a large number of neuroglia cells scattered throughout its substance. These were in an active state of division, and had very little protoplasm around their deeply-stained nuclei. Processes of connective tissue passed in from the surface of the white matter, and broke up into a somewhat coarse network, and in the meshes of this reticulum were groups of what appeared in transverse section to be ill-defined minute

globules. There were only a few medullated nerve fibres to be seen, and lying against one or two of these a flattened branched cell of Deiters. Longitudinal sections were then made through the white matter, and showed bundles of pale non-medullated fibres passing upwards; and also occasional transverse bundles of similar fibres passing transversely from the grey matter to the white columns.

I cannot conclude without expressing my great indebtedness to Professor Turner for much kind encouragement and many valuable suggestions, both as regards the task of examining the sections and of drawing up this paper.

EXPLANATION OF PLATE XXI.

Fig. 1. $\times 200$. Transverse section through C, central canal lined by stratified epithelium. *a, a*, points where the neuroglia cells and epithelial cells are continuous; *p.m.f*, postero-median fissure dividing below to embrace canal; *a.c*, anterior commissure with band of fibres embracing canal.

Figs. 2-4. $\times 500$. Anastomoses of cells from antero-external groups at different levels.

Fig. 5. $\times 500$. Anastomosis of cells from antero-internal group.

CONTRIBUTIONS TO THE STUDY OF NUCLEUS-DIVISION, BASED ON THE STUDY OF PRICKLE CELLS. By SHERIDAN DELÉPINE, M.B. EDIN., *Lecturer on Histology, St George's Hospital, London.* (PLATE XXII.)

Introductory Historical Remarks.

It is now generally recognised that in normal and specially in morbid stratified epithelia, the greatest number of the cells present at their periphery markings or projections which have been compared to teeth, ridges, prickles; hence the names they have received from various authors, viz., *denticulate cells*, "*cellules dentelées*," *prickle cells*, &c. These cells were probably first noticed by Max Schultze and Virchow, but since then little notice seems to have been taken of them. They were at first supposed to have a ridged or denticulate surface, and it was argued that, the ridges of one cell penetrating into the grooves of the neighbouring ones, a kind of dove-tail arrangement was thus obtained, and the cells were thereby strongly fastened one to the other.

Dr Martyn, however, showed this to be wrong, and demonstrated that the prickles of adjacent cells correspond by their apex, forming thus bridges between these cells. It was then supposed that between these bridges there existed a *system of small lymphatic channels*, and that this arrangement was more or less subservient to the processes of nutrition in epithelial tissues. This, I believe, is all that was known on this subject, when several years ago I began the following researches, under the impression that both statements and hypothesis were unsatisfactory or insufficient to explain what could be seen even in moderately good preparations. The study of several specimens soon led me to the belief that there was *something more than mere accidents of surface* in the markings exhibited by these cells, that they must be *less special to epithelial tissues* than was supposed, and probably intimately connected with the internal structure of the cell, but for a long time I was unable to see how.

The works of Flemming and Strassburger were then making the process of nucleus division (karyokinesis) familiar to the histological student. Two or three years later, during the winter 1881-82, Professor Hamilton, who had then charge of the Laboratory for Pathological Investigation at the Royal Infirmary of Edinburgh, had the kindness to give me a great number of tumours to examine, with the special purpose of observing the process of karyokinesis in morbid tissues, and while thus occupied I came across a number of epithelial tumours, in which prickles cells were more distinct than in any specimen I had ever seen. The study of these preparations soon led me to the conclusion that, between the nuclei of the cells of an epithelium (in a state of active growth?) there are bundles of fine fibrils, which, owing to certain optical properties and other circumstances, are more distinct at the periphery of the cells than at the centre, giving rise to the appearance to which the name of prickle cell is due; or, in other words, that *the prickles of prickle cells are parts of fibrils forming inter-nuclear bundles.*

Part I.—Description of Prickle Cells in Epithelial Tumours.

It is difficult to find a specimen showing this clearly, although, when once the idea is before the mind, it is easy to find full confirmation of it in very ordinary preparations.

1. TUMOURS STUDIED. METHODS USED.—I have been able to observe the facts above stated in several tumours, and especially in a *venereal wart*, an *epithelioma of the prepuce*, and an *epithelioma of the mamma*. Thin slices of these tumours were put, whilst the *tissues were still warm*, into the *hardening fluids* ($\frac{1}{4}$ per cent. solution of chromic acid, saturated solution of picric acid, methylated ethylic alcohol), and after the usual manipulations cut into very thin sections by means of *Rutherford's freezing microtome*. They were very slightly stained with carmine, picro-carmine, hæmatoxylin, saffranine, and some of the other red aniline dyes, and most of them exhibited the facts which are now to be described. The best preparations were those hardened in chromic acid, and slightly stained with *picro-carmine*, *hæmatoxylin*, or *saffranine*, and mounted in *Farrant's solution*.

2. DESCRIPTION OF THE RETE MALPIGHII OF AN EPITHELIOMA.—The following description is taken from an *epithelioma preputii*, one of the tumours referred to above. The sections were carried perpendicularly to the free surface. As usual the ordinary layers of the skin can be distinguished; the horny layer presents nothing of interest for our present purpose, but the *morbidly hypertrophied Rete Malpighii* requires a close study.

In it we can readily recognise three distinct forms of cells, forming three ill-defined strata (Plate XXII. fig. 1).

1. The deep or small cells.
2. The intermediate or medium size cells.
3. The superficial or large cells.

(a) *Deep Cells of the Rete Malpighii*.—These cells, which are in direct contact with the derma (corium), are very small; most of them are about the size of a leucocyte, some are larger, few are smaller. They are very variable in shape, some are almost cubical, others are elongated, somewhat cylindrical, others again are spindle or pear shape, these last forms are mostly found at the apex of papillæ, and there, sometimes, one of their tapering ends seems to penetrate into the underlying tissues, whilst elsewhere they are as sharply separated from the connective tissue of the corium as if there were a basement membrane between the two (fig. 2). Some of these cells are separated from each other by a slight space; this is specially noticed at the apex of the papillæ. These narrow spaces go diverging from the papilla towards the surface of the tumour, and separate more or less distinct rows of cells, which remain connected by their tapering ends and prickles, as will be shown later on.

These cells have a comparatively very large nucleus, which is, as a rule, more bulky than the rest of the cell, indeed, in many places it is difficult to recognise clearly the protoplasm surrounding the nucleus. Owing to this the nuclei appear closely crowded together. They are remarkably unequal in size, some, evidently just dividing, are quite as large as two of the smallest cells put together. A few of these nuclei have contracted and become separated from the surrounding protoplasm, there remaining a clear space between the two. In a few cases distinct fibrils are seen crossing over that space, ex-

tending between the contracted nucleus and the protoplasm of the cell.

Some of these cells are seen to divide, and near the apex of one papilla the dyaster stage of the process can be observed pretty closely, the division taking place in a direction parallel to the surface of the papillæ, with which, therefore, the two daughter cells remain in contact; in other places the division is evidently taking place in a direction more or less perpendicular to the surface of the papilla. The relative position of the nuclei, and the relation of the various cells, specially near the tip of the papillæ, are too suggestive to leave any doubt in the mind as to the truth of these assertions (fig. 2).

In many places there is only one layer of these cells on the surface of the papilla, in others there are two and three layers. It is probable that these differences, as well as those observed in the shape, are, at least partly, due to the relation of the plane of section to the axis of the papilla; this is so obvious that it is sufficient to mention it.

These cells are not prickled all over their surface. For instance, their deep aspect, that is, the one in contact with the cutis vera, never shows any distinct prickles. In some (very few) of the spindle-shaped cells above referred to, it is not possible to say that there is no prickle to be found on the deep side, but there is certainly no distinct evidence of their presence. The distal side of these cells, on the contrary, is invariably prickled, and the sides show often very distinct denticulations; these are not found always regularly round all the periphery of the cells, but often only in limited portions, which evidently correspond to the direction of the nuclei of some neighbouring cells either of the same layer or of some superficial layers. Where the cells are somewhat separated from each other, these prickles may form little bundles of fibrils, bridging here and there over the intermediate space, and connecting the cells together. Very little more can be seen distinctly in this deeper stratum, and it is only right to say, that even what has been just described is not always easy to see. The bundle appearance is rather exceptional, and in most places the cells are more or less regularly prickled all over, except on their deep surface of attachment.

(b) *The intermediate cells, or those immediately superficial to the last, are gradually passing towards a type which may thus be briefly described (fig. 3).*

The cells are polyhedral, more or less regular in their outline, and sometimes elongated through the effect of pressure. They vary much in size, the deeper ones being hardly larger than the cells of the last layers, whilst the more superficial ones are many times larger than these cells, some of their nuclei being quite as large as the whole of one of the smallest cells of the deeper layer. They have a large nucleus, absolutely larger than the great majority of nuclei of the deepest cells, but comparatively to the size of their cell smaller, for the nucleus here forms only a small part of the whole bulk of the cell.

Many of these nuclei seem to have a wall with a double outline, but this is very often difficult to observe with certainty, for a slight contraction of the nucleus within the cavity which it occupies in the cellular protoplasm would produce an appearance exactly like the one observed, whilst, on the other hand, this double contour often encloses a crescentic space, which would be best accounted for on the supposition of a contracted and slightly displaced nucleus.

This view is also supported by the fact that many nuclei are considerably contracted, leaving around them an empty space, the contracted mass occupying the centre or one of the sides of the cavity. In many cases this cavity, which generally corresponds in size to the largest nuclei, is quite empty, this giving rise to the appearance which has been called vacuolated or vesicular nucleus. It is, however, probable that vacuolation can seldom be the explanation of this appearance, which comes probably from the opening of the nuclear cavity by the section knife, and the subsequent dropping out of the nucleus (contracted under the influence of hardening agents) during the process of mounting. In some, but very few, cases a few fibrils connect the nucleus to the sides of the cavity. It may be mentioned also that, although sometimes the walls of this cavity are slightly irregular, they in the great majority of cases present a very smooth outline, in which it is almost never possible to distinguish with certainty a double contour.

The shrunken nucleus is often very irregular in shape; some-

times it retains its round or oval form. Within it there are granules or particles, and sometimes convoluted masses, an equatorial plate, two polar plates, or two or more rounded nucleoli, very deeply stained, all things indicating a state of active division, but not always corresponding in appearance to what has been described by writers on karyokinesis, probably owing to the staining processes being different (or, possibly, as these nuclei do not always exhibit a large increase of size, the difference is perhaps due to the fact that the whole karyokinetic process is not gone through every time a cell divides, the process being probably intermittent, a complete rejuvenescence being required from time to time to maintain the proliferating energy).

These intermediate cells of the Rete Malpighii are generally separated by what appears to be thick walls (fig. 4), but the double outline of these walls is somewhat blurred, and not easy to define clearly. Sometimes it seems to be composed of a material staining less deeply than the general mass of the protoplasm of the cell. At other times there seems to be a narrow space between the adjacent cells, space across which bright or dark filaments (the so-called prickles) stretch, connecting the cells together.

But a careful examination of those short intercellular filaments will show that their course, length, arrangement, and general appearance vary very much in the various parts of the periphery of the cells. In some places it is difficult to see between two cells anything more than *alternating bright and dark spots* (fig. 6). In other places these dots seem to elongate, forming *short fibrils*, some of which penetrate more or less into the adjacent cellular territories. At other points these fibrils form distinctly, *short bundles* evidently running in the direction of one nucleus, or of the nuclei of two cells (fig. 7). Sometimes again some of these *bundles are seen to spring from a nucleus and go from it to the periphery* of the cell, diverging from each other (fig. 9). In still rarer spots such *bundles are seen to connect two nuclei* (fig. 8), and still more rarely a *single nucleus can be distinctly seen to be united to two or more neighbouring nuclei by two or more bundles of fibrils* (fig. 9). These bundles of fibrils do not always run between the nuclei of cells

in close apposition, but they have sometimes to run for some distance between two indifferent cells before reaching their destination (fig. 10). In such cases it does not unfrequently happen that these fibrils are crossed by fibrils going in another direction, thus producing a kind of network with quadrangular meshes (fig. 10). In other places these bundles are cut more or less obliquely across (fig. 11), and then they appear under the form of a rounded, oval, or triangular body dotted all over, the dots corresponding in size to the fibrils. These transverse sections can be seen between two cells, where they are generally much flattened, or between three cells, when they are generally more or less triangular. Sometimes they have been cut at a short distance from the nucleus from which they spring, and when the bundle is going perpendicularly to the plane of section the dots of the transverse section seem to belong to the nucleus, the outline of the bundle corresponding almost exactly with that of the nucleus both in size and shape; but generally these bundles are more or less oblique, and their section is consequently a more or less elongated oval surface, and somewhat distant from the nucleus, which it may simply overlap, or from which it may be quite distinct and separated. In these oblique bundles it is often very easy to see how the longitudinal fibrillation of the bundles and the dotting of their section correspond. In certain parts almost the whole surface of one cell seems to be covered with dots; in these cases there is evidence that the plane of section has passed very near the surface of the cell, which has been, so to speak, shaved. The direction of the fibrils is peculiar when they reach the nucleus (fig. 9), for instead of penetrating into it many fibres seem to pass round it, and sometimes they can be followed into a bundle starting from the same nucleus in another direction (this arrangement is very much like that of the fibrils of the processes of a large branching nervous cell within the cell substance). The fibrils do not stain so deeply as the cell substance, if they stain at all, but they are separated by a material which appears very dark, either owing to its having a much inferior refracting power, or perhaps both on that account and because it stains deeply. At the periphery of the cells this contrast is very marked, and there the highly refracting fibrils

appear as short prickles, on account of the contrast which makes them more striking there (figs. 4 and 5). The fibrils are apparently uniform in thickness. The number of fibrils in a bundle varies very much; very often not more than two or three can be distinctly seen in a longitudinal section of a bundle, but more generally there are about five, six, or more fibrils, which would produce a total average number of about forty in the bundle, but, as the size of the bundles varies, it has not been thought useful to find the exact number of fibrils contained in each bundle for the present (fig. 12). There is another important appearance to notice, where the cells have been elongated by pressure, or perhaps by rapid growth of the underlying tissues. This elongation is often seen at the sides of very elongated papillæ, or of papillæ which are very close the one to the other, or also in the neighbourhood of cell nests. In these cells the individual bundles of fibrils are running more or less parallel to each other, and become indistinguishable, or they cross at very acute angles. The whole substance of the cell appears fibrillated, and where the cell is very long and fusiform, the appearance is exactly the same as that presented by a nucleated fibre of white connective tissue. Even in this layer, and in the midst of these intricate fibrils, long bundles of fibres may be seen running between distant nuclei. There are also short fibrils running between the cells, more or less perpendicularly to their long axis, and less closely packed, but these are obscured by the great abundance of the other longitudinal fibrils.

(c) The cells of the most superficial layer are of secondary interest for this study. Their appearance varies much; they are very large, more or less polyhedral, getting gradually flattened towards the surface. They are larger than the cells of the middle stratum. Their nucleus has about the same size as in the last cells, and therefore is smaller compared to the bulk of the cells. They also are less often contracted, and show the vesicular appearance much more seldom. Their walls or partitions are very thin, and do not show any distinct double contour, although they are very sharply marked, and the prickled appearance is in some places hardly distinguishable unless a very powerful light is used. These prickles do not seem to extend up to the nuclei, and are

more or less regularly distributed all over the surface of the cell. These cells present therefore the appearance which is usually attributed to prickled cells. However, in certain specimens almost everything that has been described in the last layer can be recognised here.

To sum up, we may say that in the Rete Malpighii we find three strata of cells, which strata are not sharply defined, but gradually merge the one into the other.

The deeper stratum, which is the thinnest, is composed of one, two, or three rows of small cells, with comparatively enormous nuclei, and having prickles irregularly distributed on their surface, except on the deep surface of attachment, which is generally smooth.

The middle stratum, which is much thicker than the last, composed of several layers of polyhedral cells, sometimes elongated. The cells are of medium size, and show the internuclear bundles of fibrils, giving rise to the prickled appearance very well, the cells being separated by thick walls or spaces with blurred outlines. The nuclei are much larger than in the deep stratum, but are smaller when compared to the general bulk of the cell.

The superficial stratum, composed of very large cells, becoming more and more flattened towards the surface. The cells show the internuclear filaments very indistinctly, except at the intercellular partitions, which are very thin and sharply defined.

3. ARGUMENTS IN FAVOUR OF THE TRUTH OF THE NEW DESCRIPTION OF PRICKLED CELLS.—This description, although very incomplete, will however sufficiently show on what grounds the statement which was put forth at the beginning has been established. However, as several objections may come to the mind of the reader of these lines, it may be as well to add a few considerations in support of the statement.

I. *The existence of internuclear bundles of fibres is sufficient to explain the prickled appearance.*

1. *Where the bundles are not distinct and the whole periphery of the cell is apparently equally prickled*, nothing forbids the supposition that the prickles are produced by bundles running in various directions, for it is known that each part of a divided

nucleus goes on dividing again and again, at least for a certain time, and it is evident that the newly-formed nuclei cannot move in the direction of those previously formed, the result of this being that the *secondary cells must be grouped all round the original one*, and if the nuclei are connected by bundles of fibres as we say they are, these bundles will radiate from the original nucleus towards various points of the periphery of the cell (fig. 9). Moreover, *all the prickles found at the periphery of a cell are not necessarily parts of fibrils belonging to that cell*, but may be due to the passage of bundles going between other cells tangentially to the one we are considering.

2. *Where the prickles seem to be quite superficial, and not connected with any filament penetrating the cell, or where the surface of the cell appears to be ridged*, it may be supposed, and this can actually be seen in some cases, that bundles of filament have been flattened between two cells, appearing as dots or very short threads when cut across, or as lines or ridges when the section is parallel to their direction (figs. 10 and 11).

3. *Where the prickles seem to be due to the crossing of fibrils, enclosing quadrangular or polygonal spaces*. The last hypothesis holds good, but it must be supposed, in addition, that two or more bundles of fibres running in various directions are superposed (fig. 10).

4. *Where the fibrils or prickles are unequal, and apparently penetrate unequally into the cell substance*. The explanation is simply that, owing to their various directions, the fibrils have been cut more or less obliquely, and that consequently longer or shorter portions of them are included between the planes of section (figs. 6, 7, and 8).

5. *The prickled appearance is due to the fact that the fibrils are much more distinct at the periphery of, and between, adjacent cells than in the centre*. This can be explained by the fact that the centre of the cell is more deeply stained than its periphery, and that the bundles, by penetrating into the protoplasm, lose thus their distinctness. But this would not be a sufficient explanation, if even it were partly correct, which is doubtful notwithstanding its apparent likelihood; for how would this explain the partial or complete disappearance of the fibrillation from the body of more superficial cells,

which stain less deeply than that of the deep cells? Nor can it be said that the fibrils become apparent at the periphery on account of their being stained, for neither they nor the cell wall take stains well. It is more likely that we have to do here with a double phenomenon of refraction and reflexion of light (figs. 14 and 15). Where two cells come in contact there are one or more surfaces of cleavage, which are seldom perpendicular to the planes of section, hence a part of the light transmitted through the section is reflected back, and another part is deviated or refracted, this producing a darkening of the region corresponding to the partition between the cells; on the other hand, the fibrils (which are cylindrical and therefore refract light strongly) are not cleaved, but pass directly from one cell into the other, so that they remain bright, as they pass through the dark portion mentioned above, and the contrast makes them appear much more distinct, and almost as elongated dots at the intercellular surfaces or wall. In many places, in addition to this, the protoplasm of the cells having contracted slightly, there remains a space between them over which the fibrils cross (fig. 5) and become extremely distinct. The two borders of such spaces are often very dark, for the reasons explained above. However, where such a tearing asunder takes place, it is suspected that something more than the internuclear fibrils remain binding the cells together at certain points. It has been said that the cells of the superficial layers of the Rete Malpighii show the fibrils less distinctly; this is probably owing to the transformation of the cell body into horny material; however, in certain preparations and with good light, it is remarkable to see how few cells there are that do not show fibrils in their substance. Nevertheless, it is necessary to account for this difference, and this can be done by supposing that at first the internuclear fibrils are more distinct in composition from the other parts of the cell than afterwards, and thus the first layers of horny material formed at the periphery of the cells is not so intimately connected with the fibrils than those formed later on when the fibrils have more or less altered in properties. So that there is a sharper surface of separation, and possibly a *greater difference of molecular structure and power of refraction, at the periphery than at the centre of the cell.*

II. Having now established the statement on positive evidence, it may be advantageous to add some *negative arguments*, and it can be said that, *if the prickled appearance were not due to the passage of fibrils from nucleus to nucleus, it would be impossible to explain the following facts:—*

1. *The passage of bundles from nucleus to nucleus, composed of fibrils which have each on its tract one prickle (fig. 3, drawn with camera lucida).*

2. *The divergence of a number of such bundles from a single nucleus (fig. 3).*

3. *The mixture of ridges, dots, short fibrils, crossed fibrils, which may all be observed in one cell.*

4. *The oval or triangular or very elongated dotted surfaces which are observed between cells, or in the neighbourhood of nuclei, connected or not with them by evident bundles of fibrils (fig. 3).*

5. *The extreme fibrillation of certain cells.*

III. Lastly, it may be added, that whilst it seems *certain that prickles are in most cases portions of internuclear fibrils, and that no other explanation is necessary to account for them*, yet it cannot be said positively that in all cases it has been possible to recognise distinctly this origin, and that the only thing which can be done in such a case is *to infer from the certain the nature of the uncertain*, until it can be *proved by direct observation* that the inference is erroneous.

Part II.—Histogenesis of Prickle Cells.

Having now, it is believed, established *a fact*, how can its occurrence be explained? in other words, how do prickle cells originate? *What are the internuclear bundles of fibres?*

1. *Observations.*—It so happens that it was the study of karyokinesis which led me to the preceding observations on prickle cells, and that it is in that process that I found the most satisfactory explanation of the facts observed. In some of my preparations I have been able to observe both the division of the nucleus and the bundles of fibrils just described, and thus I have had the best opportunities for comparison, since I had cells of the same tissue stained in the same fashion at the same time

and under the same circumstances. My methods, which probably were not so perfect as those of some of the observers who have written on the subject, have not allowed me to see all the details of the process as distinctly as they are described by Flemming, Strassburger, and Klein for instance; but what I have seen is sufficient to convince me of the truth of their most important statements, and on the whole my observations agree with those of Maizel and Klein, made on the membrana Descemeti of the frog, the skin of the sheep, and the epithelium of the bladder, and those of Arnold on morbid growths. I have also been able to recognise faintly the spindle filaments of Bütschli. This is the most important point in relation to prickly cells, for I have been able to convince myself that the unstained filaments stretching between the two stained parts of a dyaster corresponded in size, direction, and disposition with those of an internuclear bundle. Therefore, unless there is a fallacy in the observation, it seems evident that the origin of the internuclear bundles is established by direct evidence. And it may be said that they are nothing less than the spindle filaments (achromatin) observed during the process of karyokinesis.

2. *Arguments.*—A little thought will show how difficult it would be to find another explanation for the existence of these bundles, for it cannot be supposed that they are formed after the nuclei have separated from each other, without admitting intracellular phenomena of an entirely new kind, whilst, if it be admitted that they are *formed at the time of the separation of the nuclei*, there can be no difficulty in understanding all their characters. There is, however, another question of great importance to solve, for it might be said that these fibrils are *simply the result of the stretching of the fibrils forming the intracellular network pushed before the separating daughter nuclei*. Such an explanation would not, however, explain how the intranuclear bundle is a solid bundle of fibrils, having throughout its extent almost exactly the same diameter as the nuclei which it connects (fig. 3). If the fibrils were simply pushed before the nucleus, and stretched at the sides, the bundles would be either contracted between the nuclei or show no fibrils in their central parts, but that is not the case, for it has been seen that in cross sections these bundles are equally dotted all over (figs. 3 and 12). There

does not remain therefore other difficulties as to the origin of these fibrils than those raised by Flemming, Strassburger, and others, and it is owned that it is difficult to decide whether these fibrils originate in the cellular or in the nuclear network. *Flemming's opinion that they are of nuclear origin seems the more probable, when the dividing nucleus is observed in the dyaster stage.* But some peculiarities of the intranuclear bundles in prickly cells are difficult to explain on that supposition. Thus, *where the nucleus has contracted within its wall* (or the cavity containing it), it is almost always impossible to see fibrils stretching across the space left around the contracted nucleus, and the border of the cavity is as smooth as the periphery of the cell is ragged. In the few cases where fibrils are seen extending from the contracted nucleus to the walls of the cavity containing it, these fibrils are apparently deeply stained, and might be simply parts of the nuclear network that have not separated from the wall as readily as the others. Again, it can be noticed in many places *where there are several bundles of fibres leaving the same nucleus*, and being distinctly in focus, that some of the peripheral fibrils of one bundle are reflected into another bundle at a more or less acute angle with its original direction (fig. 9), which can be accounted for on the supposition that this appearance is due to mere superposition, or that really some of the fibrils of one bundle may be pushed before a new daughter nucleus; however, there is a still more likely explanation, and that is the following:—When a cell divides, one of the daughter cells is generally fixed, so that one-half has to move in the direction of least resistance (or more accurately, according to the resultant of the splitting force and of the resistance). The half moving must carry away part of the fibrils that were connected with the whole mother nucleus, hence a deviation of part of the fibrils which thus seem to pass tangentially to the daughter nucleus which has remained fixed (fig. 13).

Likewise, the first objection can be answered, although perhaps a little less satisfactorily, for it has been observed that often the contracted nucleus is drawn to one side of the cavity containing it, and when it appears to be in the centre, it may be supposed that it is nevertheless against the side of the cavity which is nearest to, or the one furthest from, the observer (fig. 20). It

might therefore fairly be supposed that during the process of contraction the various fibrils coming from the nucleus break sharply at the surface of separation, except those fibrils which, being strongest, owing probably to age, resist better the traction, and keep the nucleus to their side of the nuclear cavity. It may be therefore concluded, with a reasonable amount of certainty, that *the internuclear bundles of fibrils observed in the cells of stratified epithelium are the remains of the spindle filaments observed during the process of nuclear division*, and that these filaments are of nuclear origin.

Part III.—Homologues of Intranuclear Bundles of Fibrils of Epithelial Tissues in other Tissues. Influence of the Process of Nucleus Division on the Properties of Tissues.

It was intended to conclude this paper by a few remarks on the probable relation of the spindle filaments of a dividing nucleus, and the *cilia of ciliated epithelia, the striæ of the hem of intestinal columnar cells, the fibrillation of connective tissue bundles, of muscle and nerve fibres, and of nerve cells*, and also certain obscure points in relation to the *pitting of vegetable cell walls*. But space and time oblige me to defer this. I will therefore simply remark that the process of karyokinesis has been observed in all the tissues, as is shown by the following table, and that this and some observations I have made go very far in supporting the view that the process of division of the *nucleus has a great importance in relation to the cellular structure, and more generally the characters of tissues*. This table includes only the observations which have been made on the vertebrata.

[TABLE.

Authorities.	Generative Cells.	Epithelial Tissue.	Connective Tissue.	Muscular Tissue.	Nervous Tissue.	Animal in which observed.
O. Hertwig,	Ovum,	.	.	.	.	Frog.
Maizel,	.	Conjunctiva normal, inflamed.	.	.	.	Frog, newt, lizard, birds, cat, dog, apes.
"	.	Exophagus mucous membrane,	Hyaline cartilage,	.	.	Man.
"	.	Epidermis,	.	.	.	Man, rabbit.
"	.	Cancer cells,	Corneal corpuscles,	.	.	Man.
"	.	.	Descemet's endothelium,	.	.	Frog.
"	Ovum,	Embryo cells,	Embryo cells,	.	.	Fishes, newt.
"	.	Blastoderm cells,	Blastoderm cells,	.	.	Fishes, newt.
Van Beneden,	.	Blastoderm cells,	.	.	.	Rabbit.
Balfour,	Young ova,	Blastoderm cells,	.	.	.	Elasmobranchia.
"	.	Young ovary germinal epithelium,	.	.	.	Rabbit.
Eberth,	.	Normal and regenerating epithelium,	Descemet's endothelium,	.	.	Pig, rabbit.
.	.	.	Branched corpuscles of inflamed cornea,	.	.	" "
Schleicher,	.	.	Cartilage cells,	.	.	Man?
Peremeschko,	.	Epithelial cells embryo,	Connective tissue cells of embryo,	.	.	Newt (embryo).
.	.	.	Blood corp. embryo,	.	.	"
Flemming,	Sperm,	Epithelial tissue,	Connective tissue,	.	.	Salamander.
.	.	.	Blood corp. nuclei,	.	.	Embryo salamander.
Klein,	.	Epidermis,	.	.	.	.
.	.	Bladder,	.	.	.	Adult newt.
.	.	Epidermis tail,	.	.	.	Frog.
J. Arnold,	.	Carcinomata,	Sarcomata,	.	.	Tadpole.
Jakimovitsch,	.	.	.	Unstriated muscle of stomach,	.	Man.
.	Amphibian mammals.

Thus the study of nucleus division tends to complete the work of Bichat, Schleiden, and Goodsir, and to bring us a step further towards the reduction of organic matter to a unit. Whether this unit is ever to be found or not is impossible to say, but it is to be feared that it will remain the philosophical stone of the modern scientist. The cell seemed for a time to be that unit when Schleiden showed that all tissues are composed of cells and that every cell of an organism descends from one cell—the ovum. However, this does not show that cells are units; thus whilst one is doomed to die within a given time, another, exactly like the last, at first, has the power of reproducing itself, so that some of its parts may be said to be immortal. The cell therefore can only be regarded as a unit of a certain degree, but in it there are certain forces at work, of which one at least seems to be necessary to the persistence of organised matter, and that is the force which induces the division of cells. It has many points in common with the various forces governing inorganic matter; thus it apparently produces phenomena of attraction and repulsion (of polarisation), just as electricity would, and yet it gives to the organised matter powers which cannot be discovered in the inorganic world. But the discussion of these points cannot be gone into in this paper.

I cannot conclude, however, without acknowledging with gratefulness the great encouragements I have received from Professor W. Turner whilst I was prosecuting these researches. To the kindness of Professor Hamilton I owe not only the material on which they have been made, but also the direction of study which led me to successful results.

I must also express my gratefulness to my friends Mr P. Geddes, Mr J. M. Macfarlane, and Dr Woodhead, for their favourable and encouraging criticism when I brought some of the results of my inquiries before them at a meeting of the Natural Science Club of Edinburgh, in the winter 1881–82.

EXPLANATION OF PLATE XXII.

Fig. 1. Diagram showing the arrangement of the cells of the *Rete Malpighi* of a portion of the *Epithelioma Preputii*, for description see the text. (The connective tissue of the papillæ has been omitted purposely. The outlines are correct, but the cells are drawn a little larger than scale to allow their arrangement to be distinctly seen. Note the distribution of the vesicular nuclei.)

Fig. 2. The *apex of a papilla* ($\times 300$, and drawn with the camera lucida) to show as accurately as possible the arrangement of the cells of the *deepest layer*, and of the *deep cells of the intermediate layer*. The network seen in the centre of the papillæ belongs most probably to the deepest layer of the Rete Malpighi. The prickles are drawn semi-diagrammatically.

Fig. 3. Some groups of *cells of the intermediate layer* of the Rete Malpighi ($\times 300$, and drawn with the camera lucida; almost all the bundles of fibrils have been accurately reproduced; many fibrils have actually been drawn through the camera lucida).

Fig. 4. Two cells represented diagrammatically, showing their dark oblique walls, and the paler intercellular substance (see fig. 14). The *fibrils are seen crossing the space* between the two cells and looking brighter there.

Fig. 5. A part of an *intercellular space* very greatly magnified, there being nothing but the fibrils between the protoplasm of the two cells (probably contracted under the influence of reagents).

Fig. 6. Two cells, showing (*a*) on one side a cross section of a bundle of fibrils, and between the two cells dots corresponding to fibrils passing tangentially to the two cells, and perpendicularly to the plane of section (*b*), vertical projection of a section perpendicular to the two original planes of section, showing diagrammatically the thickness of the preparation, and the direction of the fibrils in a plane perpendicular to that represented in *a*.

Fig. 7. Two cells, showing a bundle of fibrils passing tangentially between two cells, and obliquely to the two surfaces of the section (*a* and *b* as in fig. 6).

Fig. 8. Two cells, showing an internuclear bundle of fibrils going from nucleus to nucleus (*a* and *b* as in fig. 6).

Fig. 9. Three cells, showing diagrammatically the connection of one nucleus with two other nuclei, and the divergence of several bundles of fibrils from a single nucleus; the tangential fibrils are also shown (see also fig. 13).

Fig. 10. Showing a long internuclear bundle joining two cells which are not contiguous, and also the crossing of the fibrils of two bundles.

Fig. 11. Diagram, showing the cross sections of—*a*, a bundle of fibrils compressed between two cells; *b*, a bundle passing between three cells; *c*, a bundle passing obliquely from a nucleus towards one of the planes of section; *d*, a bundle going almost perpendicularly to the planes of section, and almost exactly covering the nucleus from

which it comes; *e*, several bundles confused, and giving a dotted appearance to a large part of the surface of a cell.

Fig. 12. Appearance presented by the cross section of a bundle of fibrils very highly magnified.

Fig. 13. Diagram explaining how some fibrils may pass tangentially to a nucleus; the letters correspond in the two parts of the drawing.

Fig. 14. Diagram showing the influence of certain parts of a cell upon rays of light. *P*, Protoplasm; *W*, walls; *F*, internuclear fibril; *N*, *N'*, normal ray of light passing through the walls and protoplasm, and not being deviated; *n*, *n'*, rays of light which are deviated at the surface of contact between protoplasm and cell walls (surfaces of clivage); *R*, *r*, refracted rays; *R'*, *r'*, reflected rays.

Fig. 15. Diagram showing the influence of an internuclear fibril upon rays of light (letters same as above).

Anatomical Notices.

A TWO-HEADED MUSCLE EXTENDING FROM THE FRONT OF THE AXIS TO THE BASILAR PROCESS OF THE OCCIPITAL BONE (RECTUS CAPITIS ANTICUS MEDIUS). By W. J. WALSHAM, F.R.C.S., *Assistant Surgeon and Demonstrator of Orthopaedic Surgery, late Demonstrator of Anatomy, St. Bartholomew's Hospital.*

THE muscle consisted of two parallel fleshy portions, one on either side of the middle line, arising from a distinct single and centrally-placed tendon. The tendon, which measured half an inch in length, arose from the middle of the anterior surface of the body of the axis, immediately above the intervertebral disc between the axis and the third cervical vertebra. It was smooth and round, and the handle of a scalpel could be passed between it and the body of the axis. After a course of nearly half an inch vertically upwards in the middle line it bifurcated, each portion terminating in a small flattened muscle, which measured a quarter of an inch in breadth and about one inch in length. The fleshy portions of the muscle were parallel to each other, and in contact along the middle line, each being inserted into the basilar process of the occipital bone, just in front of the foramen magnum and immediately external to the median plane. The insertion was posterior to that of the rectus capitis anticus major, and internal to that of the rectus capitis anticus minor.

During eight years' experience in the dissecting room of St. Bartholomew's Hospital I have not met with a similar abnormality, nor am I aware that an account of such has hitherto been published. As it appears to be of considerable interest and rarity, I have thought it worthy of record in the *Journal of Anatomy and Physiology*.

NOTE ON A CASE OF COMPLETE ABSENCE OF BOTH SEMI-MEMBRANOSUS MUSCLES. By J. SYMINGTON, M.B., F.R.C.S.E., *Lecturer on Anatomy, School of Medicine, Edinburgh.*

THIS rare defect was found in an adult female subject dissected in my practical anatomy rooms during the summer session of 1884. A careful dissection of both thighs failed to discover any trace of either

muscle. The bones were examined in order to ascertain the condition of the surfaces to which the muscle is usually attached. On the right ischium the depression from which the muscle normally arises was quite distinct, but on the left side it was ill-defined, being apparently encroached upon by the origin of the semitendinosus and long head of biceps. There was a distinct groove on the internal tuberosity of the tibia in both limbs, although it was not quite so well marked as normal, and the surface of the depression was irregular. The internal lateral ligament was partly attached to it, but there were no traces of the tendon of insertion of the semi-membranosus. On cleaning the posterior ligament of the knee-joint it was seen to be strengthened as usual by an oblique set of fibres. However, on tracing these down towards the inner side, where they are usually connected with the semi-membranosus, they became indistinct. The semitendinosus and biceps were normal in their attachments, and they did not appear to be above the average size, as compared with the general muscular condition of the limbs. The only muscle that presented any peculiarity was the sartorius. On dissecting the popliteal space it was found posterior to the semitendinosus, and entering into the formation of the internal boundary of that space. This position would enable it to act more efficiently as a flexor of the knee, and thus in some degree to compensate for the absence of the semi-membranosus muscle. The condition of the tibia, posterior ligament, and sartorius was the same on both sides.

The semi-membranosus appears to be the only one of the three hamstrings that has been described as being completely absent. Quain, Henle, Luschka, &c., note that absence of this muscle has been observed; but, so far as I am aware, only one case is recorded, viz., that by M. de Souza, who showed a specimen to the Société de Biologie. A report of the meeting will be found in the *Gazette Médicale de Paris* for 1855. According to the latter there was no trace of the semi-membranosus either in connection with the ischium, femur, or tibia. The inner side of the popliteal space was formed entirely by the semitendinosus. The biceps and semitendinosus were said to be normal in form, volume, and attachments. M. de Souza stated that no mention of this abnormality occurs in the works of Meckel, Cruveilhier, Blandin, Lauth, or Sappey. One limb was shown to the Society, and no mention is made of the condition of the other. No reference was made to the condition of the bones, but it may be noticed that Souza's case agrees with mine in the absence of any compensatory hypertrophy of the remaining ham-string muscles. Macalister (*Trans. Roy. Irish Acad.*, vol. xxv.) refers to two cases of absence of this muscle—one by Souza, already mentioned, and another by Loschge, *Erlanger*, Abh. 1–25. The latter, however, is rather an example of a rudimentary condition of the muscle than of its complete absence, and it is described as such by Luschka (*Die Anatomie der Glieder des Menschen*, p. 412). In this case the muscle was represented by a tendon, extending from the ischial tuberosity to the internal tuberosity of the femur, and containing a small muscular belly.

CASE OF ABSENCE OF THE SEMI-MEMBRANOSUS MUSCLE; ALSO CASE OF ABSENCE OF GEMELLI AND QUADRATUS FEMORIS. By Professor W. TURNER, Edinburgh.

AMONGST the unpublished material in my dissecting room note book, I find, under the date of session 1854-5, the following note on the absence of the semi-membranosus. Dissection of an old woman who had died of diabetes, whose cellular tissue was infiltrated with a thick yellowish jelly-like fluid. The semi-membranosus muscle was wanting on each side. A thin tendinous slip, without any muscular fibres, sprang from the tuber ischii anterior and external to the biceps and semitendinosus, and reached the inner condyle, to which it appeared to be connected. It obviously represented the missing muscle.

It is well known that either the superior or the inferior gemellus may occasionally be absent in subjects, and sometimes even the quadratus femoris; but it is seldom that both gemelli are absent in the same person, or the quadratus and a gemellus.

Under the date 1865-66, I have noted the absence in the left buttock of a man of both the inferior gemellus and quadratus femoris muscles. In the right buttock of the same subject both gemelli were absent, but the quadratus femoris was half as broad again as is normal.

NOTE ON HEREDITARY DEFORMITY OF THE HAND.

By Professor W. TURNER, Edinburgh.

My attention was directed during last Winter Session to the left hand of one of my pupils, which showed a slight deformity. On speaking to him about it, he told me that he was not the only member of his family in whom it had occurred. I accordingly asked him to obtain for me as full an account as he could of the number of persons in the family in whom it had been seen. This he has very kindly done.

The deformity consisted in a shortening of the left ring finger, which was 1·2 inch shorter than the middle finger, and only 0·5 inch longer than the little finger of the same hand. The shortening was not due to absence of any of the bones, but to imperfect growth in length of the metacarpal bone, which was about three-quarter inch shorter than it ought to have been. The phalanges were normal in size.

From inquiries made by my pupil, the deformity has been noticed in members of the family for at least five, and perhaps six, genera-

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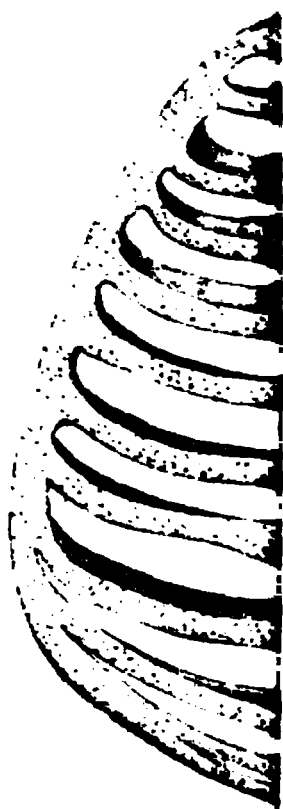
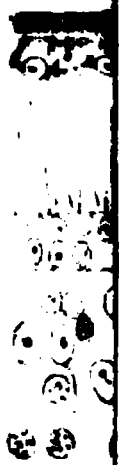
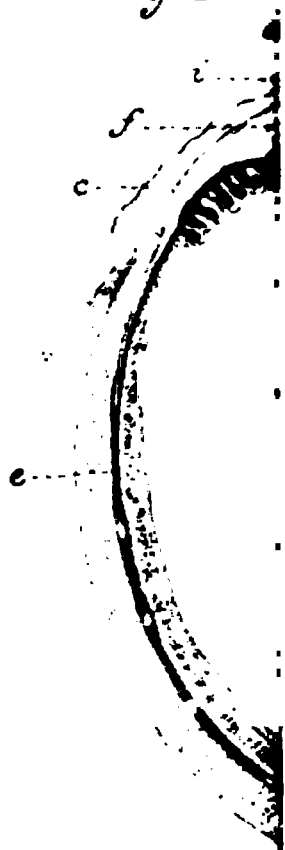
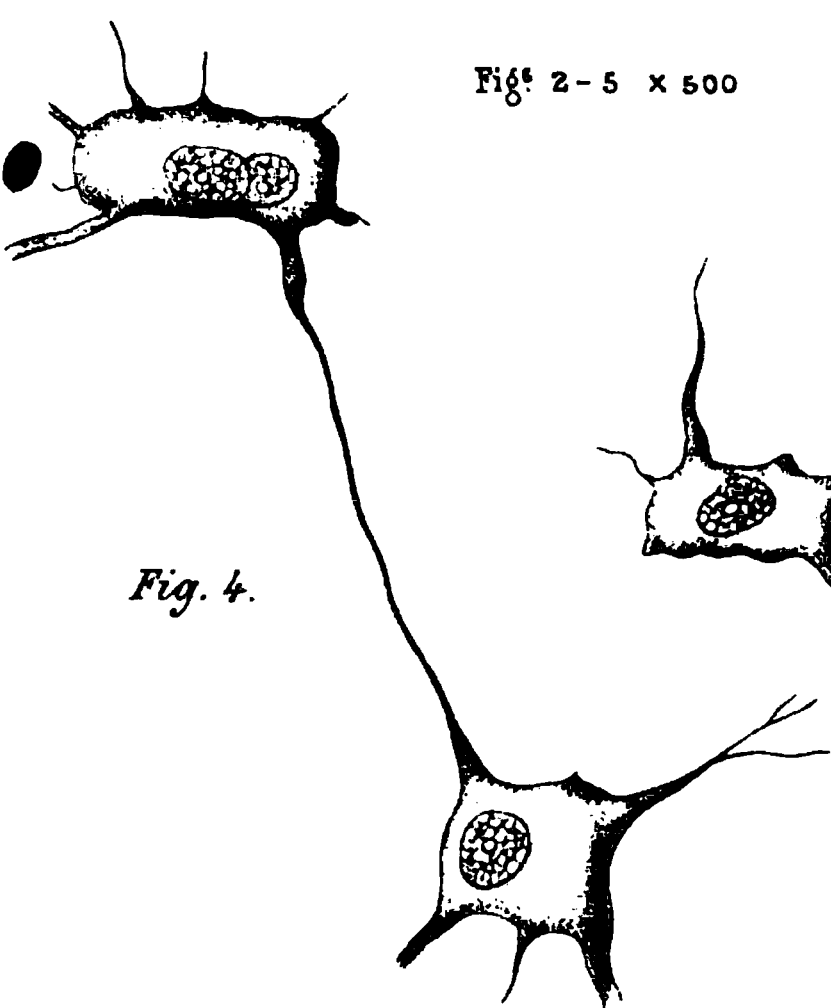
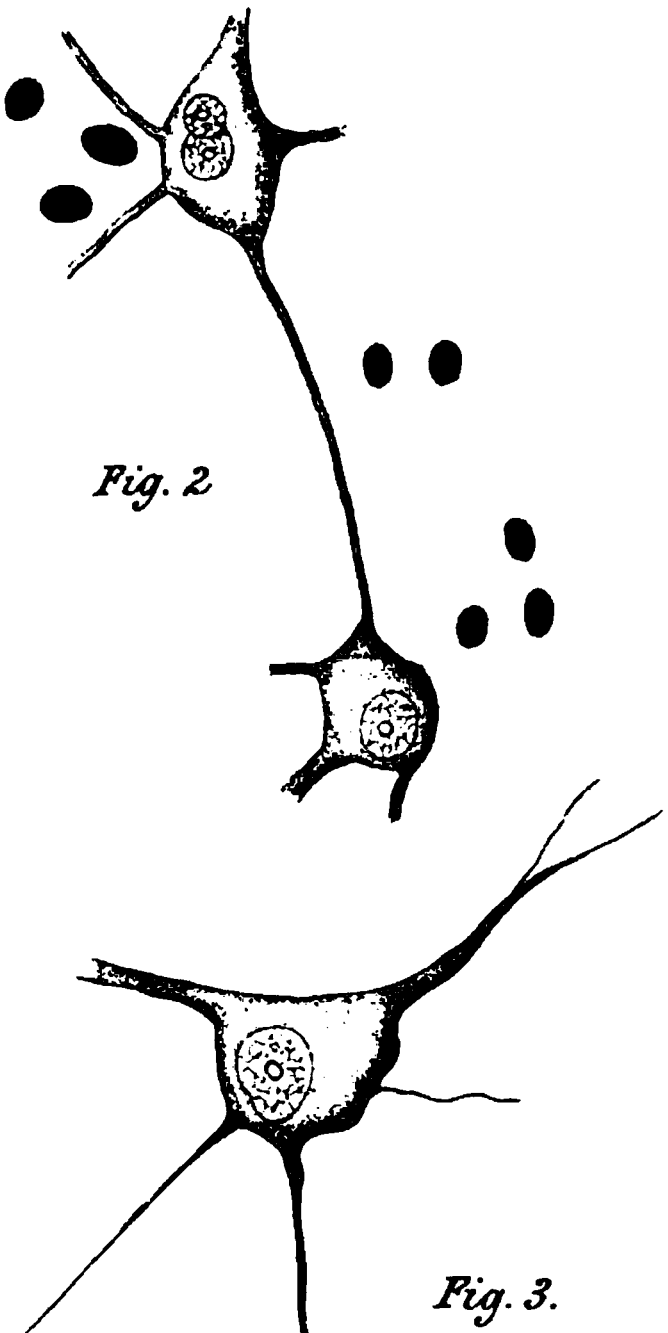
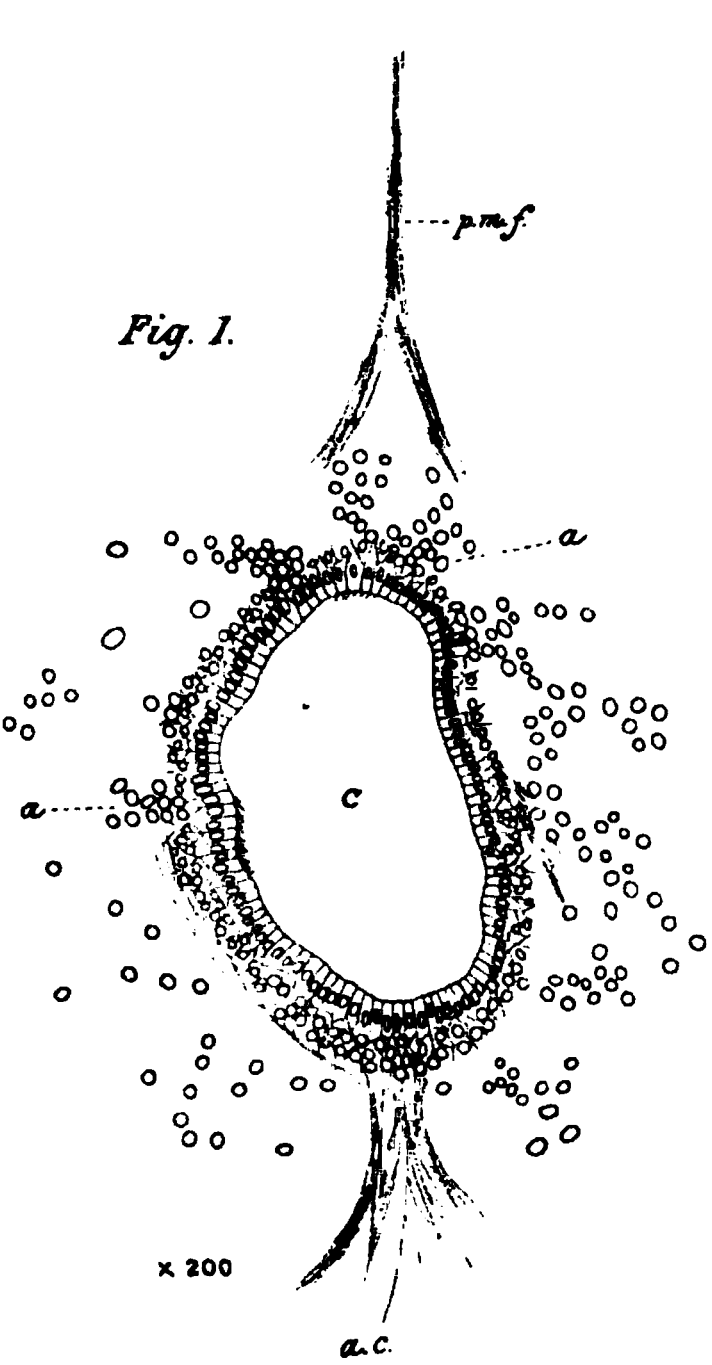


Fig. 1.





Figs 2-5 x 500

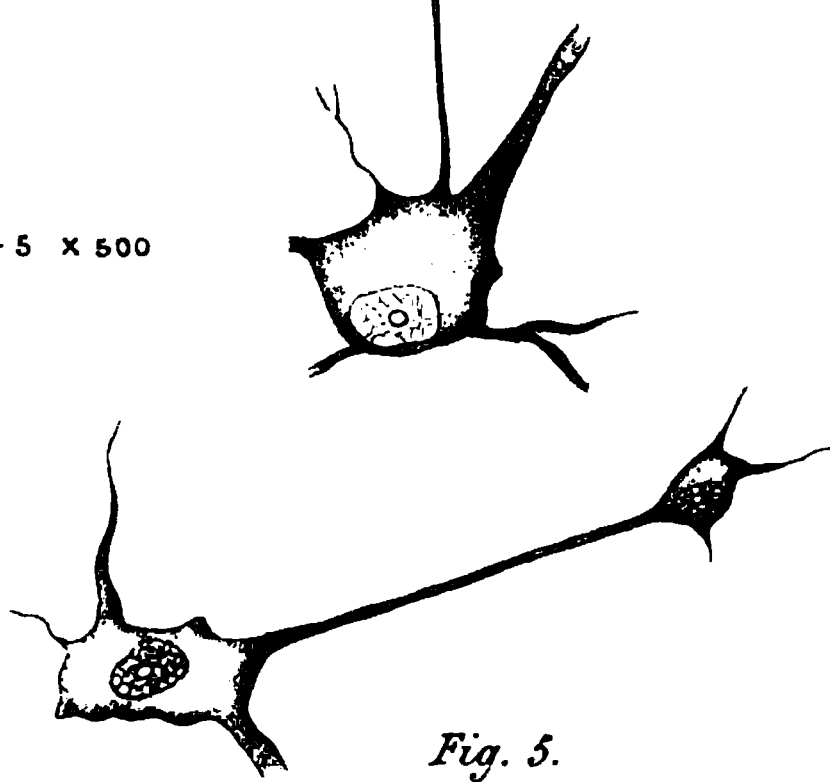


Fig 2

Fig. 1.



Fig. 3



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Fig 14

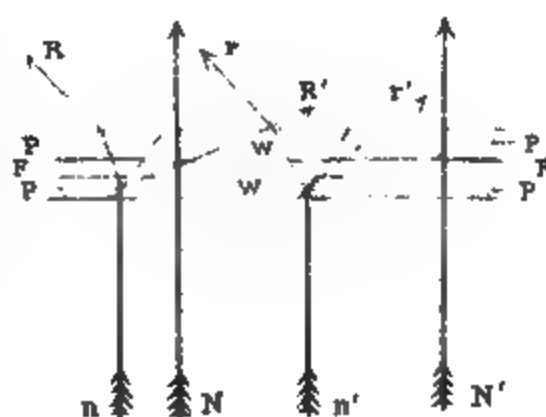
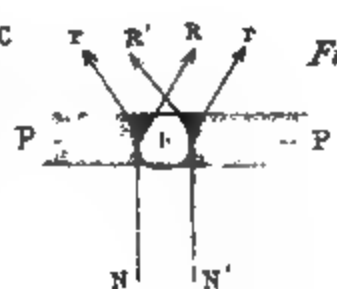


Fig 12.



Fig 13



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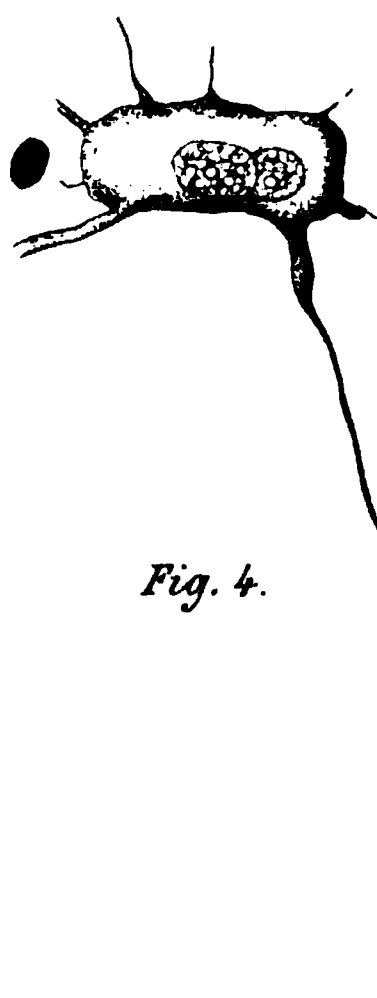
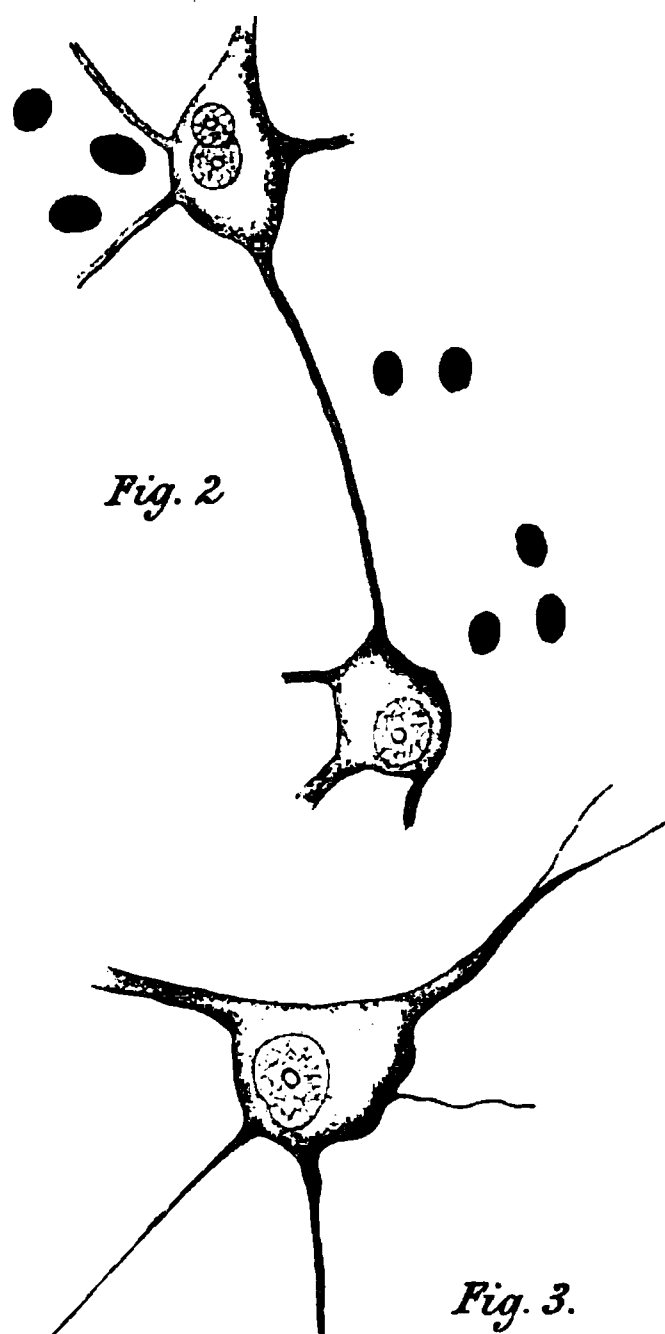
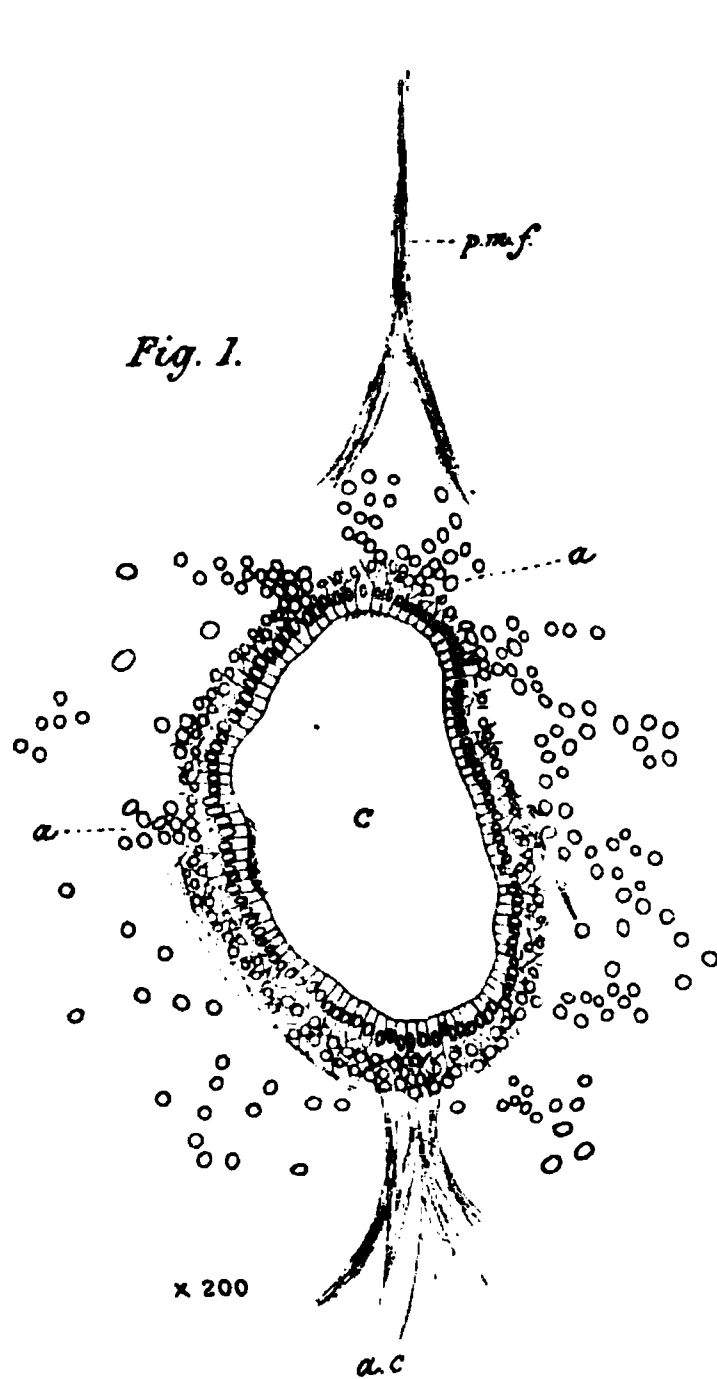
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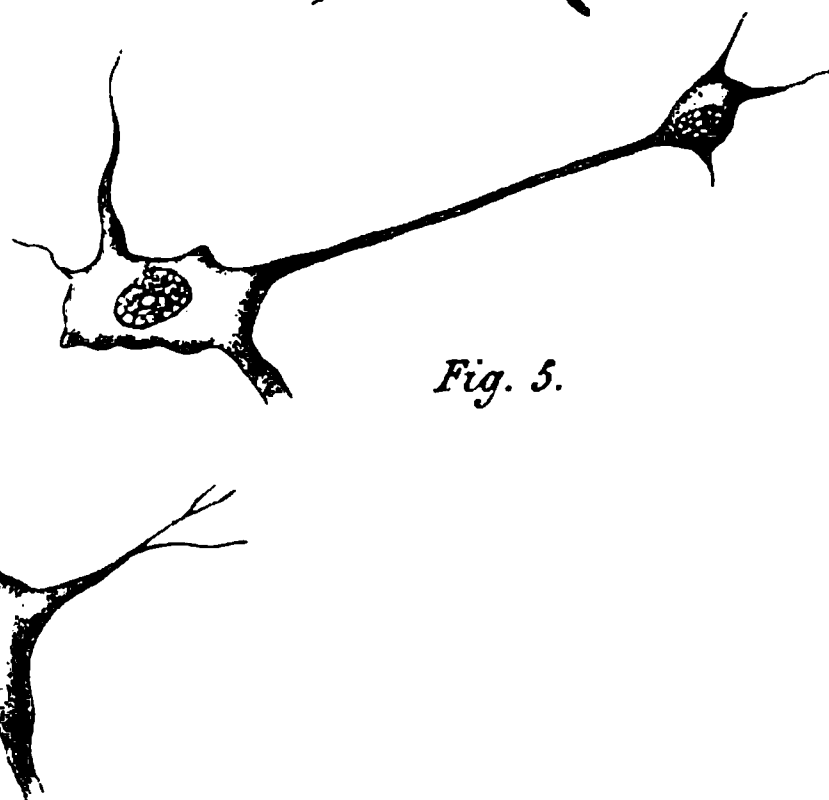


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Figs 2-5 x 500



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